NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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REPORT No. 385

WIND TUNNEL TESTS ON AIRFOIL BOUNDARY LAYER CONTROL USING A BACKWARD-OPENING SLOT

By MILLARD J. BAMBER

1931

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AERONAUTICAL SYMBOLS

1. FUNDAMENTAL AND DERIVED UNITS

	Symbol	Metric		English	
		Unit	Symbol	Unit	Symbol
Length	l	meter	m	foot (or mile)	ft. (or mi.)
Time	t	second	s	second (or hour)	sec. (or hr.)
Force	F	weight of one kilogram	kg	weight of one pound	lb.
Power	P	kg/m/s		horsepower	hp
Speed		{km/h	k. p. h.	mi./hr.	m. p. h.
		{m/s	m. p. s.	ft./sec.	f. p. s.

2. GENERAL SYMBOLS, ETC.

W, Weight $=mg$

g, Standard acceleration of gravity $=9.80665$ m/s^2 $=32.1740$ ft./sec.^{2}

m, Mass $=\frac{W}{g}$

ρ, Density (mass per unit volume).

Standard density of dry air, 0.12497 (kg-m^{-4} s^2) at 15° C. and 750 mm $=0.002378$ (lb.-ft.$^{-4}$ sec.^{2}).

Specific weight of "standard" air, 1.2255 kg/m^3 $=0.07651$ lb./ft.^{3}.

mk^2, Moment of inertia (indicate axis of the radius of gyration k, by proper subscript).

S, Area.

S_w, Wing area, etc.

G, Gap.

b, Span.

c, Chord.

$\frac{b^2}{S}$, Aspect ratio.

μ, Coefficient of viscosity.

3. AERODYNAMICAL SYMBOLS

V, True air speed.

q, Dynamic (or impact) pressure $=\frac{1}{2}\rho V^2$.

L, Lift, absolute coefficient $C_L=\frac{L}{qS}$

D, Drag, absolute coefficient $C_D=\frac{D}{qS}$

D_o, Profile drag, absolute coefficient $C_{D_o}=\frac{D_o}{qS}$

D_i, Induced drag, absolute coefficient $C_{D_i}=\frac{D_i}{qS}$

D_p, Parasite drag, absolute coefficient $C_{D_p}=\frac{D_p}{qS}$

C, Cross-wind force, absolute coefficient $C_C=\frac{C}{qS}$

R, Resultant force.

i_w, Angle of setting of wings (relative to thrust line).

i_t, Angle of stabilizer setting (relative to thrust line).

Q, Resultant moment.

Ω, Resultant angular velocity.

$\rho\frac{Vl}{\mu}$, Reynolds Number, where l is a linear dimension.

e. g., for a model airfoil 3 in. chord, 100 mi./hr. normal pressure, at 15° C., the corresponding number is 234,000;

or for a model of 10 cm chord 40 m/s, the corresponding number is 274,000.

C_p, Center of pressure coefficient (ratio of distance of $c.\ p.$ from leading edge to chord length).

α, Angle of attack.

ϵ, Angle of downwash.

α_o, Angle of attack, infinite aspect ratio.

α_i, Angle of attack, induced.

α_a, Angle of attack, absolute. (Measured from zero lift position.)

γ, Flight path angle.

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By MILLARD J. BAMBER
Langley Memorial Aeronautical Laboratory

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

NAVY BUILDING WASHINGTON, D. C.

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REPORT No. 385

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By Millard J. Bamber

SUMMARY

This report presents the results of an investigation to determine the effect of boundary layer control on the lift and drag of an airfoil. Boundary layer control was accomplished by means of a backward-opening slot in the upper surface of the hollow airfoil. Air was caused to flow through this slot by a pressure which was maintained inside the airfoil by a blower. Various slot locations, slot openings, and wing pressures were used. The tests were conducted in the 5-foot atmospheric wind tunnel of the Langley Memorial Aeronautical Laboratory.

The quantity of air flowing through the slot per unit time was measured and is presented in coefficient form. A coefficient is derived from which the power required to maintain the air flow through the slot may be computed.

The effect of each variable is illustrated by characteristic curves. A discussion indicating the advantages which might be possible by the application of boundary layer control to an airplane is included.

A discussion of the various forces produced on the airfoil by this type of boundary layer control and their resultants is given in Appendix I.

Under the test conditions, the maximum lift coefficient was increased about 96 per cent for one slot arrangement, and the minimum drag coefficient was decreased about 27 per cent for another, both being compared with the results obtained with the unslotted airfoil. It is believed from the results of this investigation that the above effects may be increased by the use of larger slot openings, better slot locations, multiple slots, improved airfoil profiles, and trailing edge flaps.

INTRODUCTION

The efficiency of airplanes could be materially improved if the flow of air around the wings and other parts could be made to approximate more closely that of an inviscid fluid. If this could be accomplished then, according to the Kutta-Joukowski theory, the lift would continue to increase up to about 90° angle of attack and the profile drag would remain small.

Consider an airfoil with a sharp trailing edge and of infinite span as being moved through an inviscid fluid at rest. The fluid would receive an acceleration over the forward part of the airfoil and a deceleration over the rearward part. In order for the fluid to come to rest at the trailing edge, all the kinetic energy absorbed by the fluid while being accelerated is required to overcome the pressure gradient during the deceleration.

In the case of air, a viscous fluid, kinetic energy is lost by friction between the layers of air moving at different velocities near the surface of the airfoil. Owing to this loss the remaining kinetic energy is less than that required to overcome the pressure gradient, and consequently at the trailing edge the air does not come to rest but has a velocity component in the direction of the wing motion. Thus a layer of air, termed the "boundary layer," is dragged along by the surface of the airfoil, and the force required to maintain this layer is expressed in terms of what is known as profile drag. This layer is also the chief cause of the failure of the lift to increase continuously with the angle of attack up to the theoretical maximum for an inviscid fluid.

The effect of the boundary layer on the lift and profile drag of an airfoil varies with the angle of attack. At small angles the profile drag is small, but it increases with the angle as a region of turbulent air, which extends forward from the trailing edge, develops on the upper surface. A further increase in the angle of attack is accompanied by a rapid increase in the size of the turbulent region as the angle of maximum lift is approached, and for this reason the lift no longer increases with the angle and the profile drag becomes large. If this region of retarded and turbulent air were kept as small at large angles of attack as it is at small angles, it might be expected that the lift would continue to increase with the angle and the profile drag would remain small. It follows from the above statements that an air flow approaching that of an inviscid fluid could be maintained if the boundary layer could be reduced by adding energy to it, or if it could be removed as fast as it is formed.

Previous investigations have shown that the boundary layer can be controlled by the above methods. Energy has been added to it by means of jets and by movable surfaces. The jet for adding the energy has been furnished by an auxiliary airfoil near the leading edge of the wing (references 1, 2, and 3), by a nozzle held in front of the airfoil so as to discharge air rearward over the upper surface (Reference 4), and by backward-opening slots in the upper surface of the airfoil (references 5, 6, 7, 8, and 9). Rotating cylinders have also been used to form a portion of the airfoil surface near the leading edge, thus accelerating, or at least preventing retardation of, the air flow with respect to this part of the surface. (References 10 and 11.) Removal of the boundary layer has been accomplished by sucking it into the airfoil through slots or perforations in the upper surface. (References 4, 6, 7, 9, 12, 13, 14, and 15.)

In the present investigation, which was conducted in the 5-foot atmospheric wind tunnel at the Langley Memorial Aeronautical Laboratory, the boundary layer was controlled by the action of air flowing through a backward-opening slot in the upper surface of the airfoil. A preliminary report of this investigation has been made. (Reference 16.) These experiments included not only the acceleration of the boundary layer by pressure but also its removal by suction. The slot was adjustable in size of opening, as well as in location along the chord. This type of slot was chosen from among several previously tested (reference 9), because when not in use it had the least detrimental effect upon the aerodynamic characteristics of the airfoil. The tests were made with the model mounted between two end plates which were sufficiently large to give practically 2-dimensional flow.

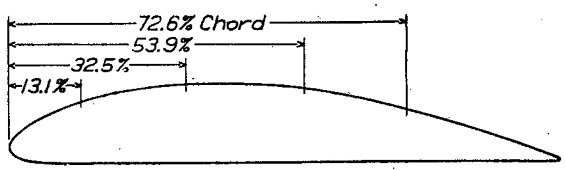

FIGURE 1.—N. A. C. A. 84–M profile showing slot locations

MODELS AND APPARATUS

The airfoil used in the tests had the N. A. C. A. 84–M profile, Figure 1, the ordinates of which are given in Table I. The upper surface profile was practically an arc of a circle, thus allowing the part of the arc containing the slot to be used in various positions without appreciably modifying the profile. The airfoil chord was 15 inches and the span was 25¼ inches. This size of chord was used to facilitate the construction of the relatively small parts comprising the slot.

TABLE I.—N. A. C. A. 84–M PROFILE ORDINATES

Station in per cent of chord	Ordinates upper surface per cent of chord	Ordinates lower surface per cent of chord
0.000	2.920	2.920
1.25	5.270	1.212
2.50	6.410	.673
5.00	7.930	.173
7.50	9.150	.001
10.000	10.090	.000
12.000	10.750	.000
16.000	11.930	.000
20.000	12.855	.000
25.000	13.680	.000
30.000	14.160	.000
40.000	14.475	.000
50.000	13.910	.000
60.000	12.425	.000
70.000	10.250	.000
80.000	7.580	.000
90.000	4.285	.000
95.000	2.606	.000
100.000	[1] .253	.253

[1] T. E. radius=0.253.

A view of the model with part of the upper surface removed and the slot installed at 53.9 per cent of the chord is shown in Figure 2. The airfoil was mads hollow to provide for the passage of air to or from the slot. The upper surface was made up of a number of mahogany strips, three-fourths inch wide, so that any three could be replaced by the slot assembly. These strips, together with the laminated mahogany leading and trailing edges and an aluminum lower surface plate, were attached by screws to four steel ribs. The ribs had their central portions cut away to allow for the free passage of the air.

The details of the slot construction are shown in Figure 3. The front and rear brass sections were fastened rigidly to the steel ribs by machine screws. The center and rear sections were connected by spring steel which formed the upper surface of the airfoil at this place. The slot opening was varied by the four adjusting screws which passed through the center section and into the ribs. The three levers which were attached to the center section were used to hold the spring steel to the desired curvature. The slot opening was easily adjustable to within ± 0.003 inch at any point.

The airfoil was mounted in the tunnel between circular disks as shown in Figures 4 and 5. This type of installation was chosen because it permitted the use of the large chord airfoil, and because it was particularly adapted to the transfer of air to or from the airfoil without affecting the measurement of the lift and drag forces.

The airfoil was mounted on a vertical tube which passed through the airfoil parallel to the span. The lift and drag forces were measured at the upper end of the tube; the lower end was supported on a pivot. The air duct was led in to the open end of the hollow airfoil through the mercury seal.

The air duct was connected to an electrically-driven Roots type blower. The pressure maintained inside the airfoil was measured by means of an alcohol manometer, which was connected to a perforated tube, which extended the full span inside the airfoil. For a pressure reference, the other side of the manometer was connected to a static plate located on the tunnel wall just ahead of the model position. The quantity of air per unit time flowing to or from the airfoil was measured by the pressure difference across a sharp edge orifice meter, which was installed in the air duct between the blower and the airfoil.

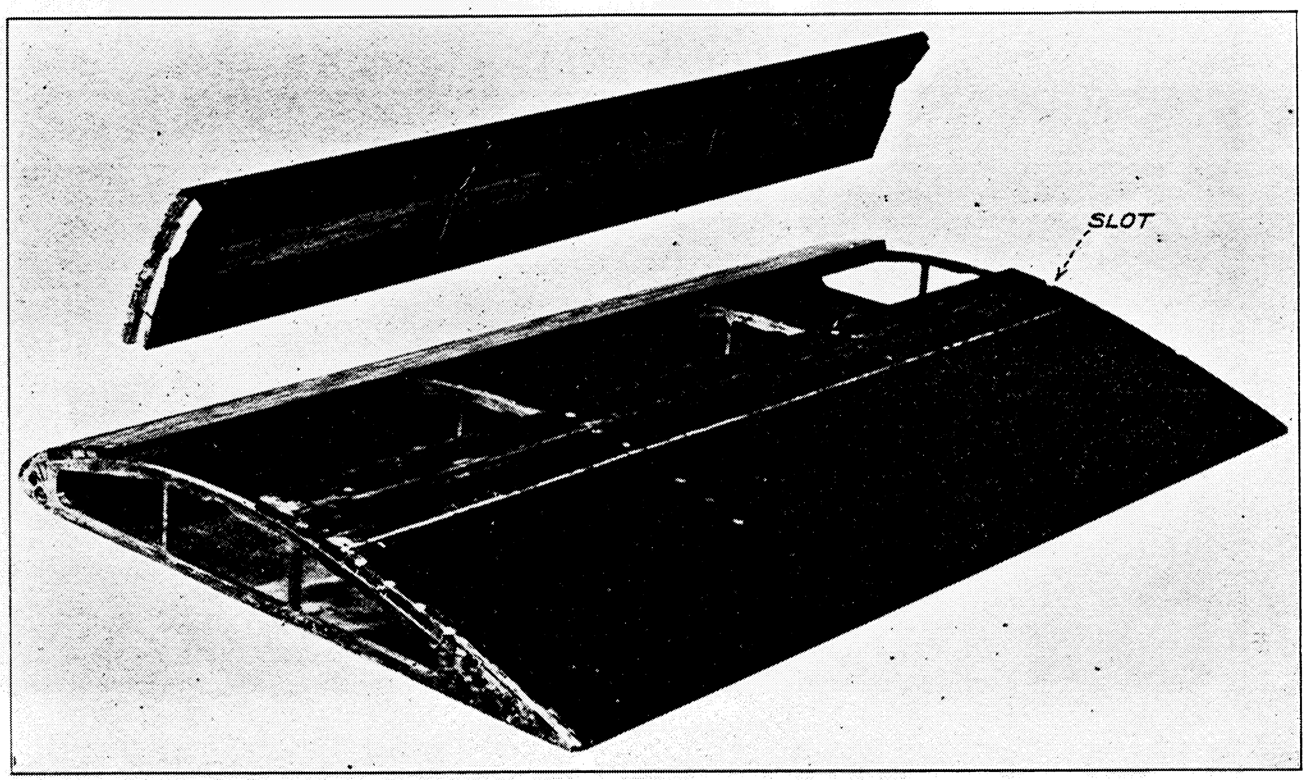

FIGURE 2.—N. A. C. A. 84–M airfoil with part of upper surface removed and slot at 53.9 per cent of chord

TESTS

Calibration tests were first made to align the apparatus with respect to the air stream of the tunnel and to determine the velocity distribution in the test section and the drag of the end plates which were attached to the ends of the airfoil.

The airfoil tests were divided into five main groups:

1. No slot.
2. Slot location 13.1 per cent of chord from L. E. (1.97 in.).
3. Slot location 32.5 per cent of chord from L. E. (4.88 in.).
4. Slot location 53.9 per cent of chord from L. E. (8.09 in.).
5. Slot location 72.6 per cent of chord from L. E. (10.90 in.).

For each slot location four openings of slot were tested:

1. Slot opening 0.167 per cent of chord (0.025 in.).
2. Slot opening 0.333 per cent of chord (0.050 in.).
3. Slot opening 0.500 per cent of chord (0.75 in.).
4. Slot opening 0.667 per cent of chord (0.100 in.).

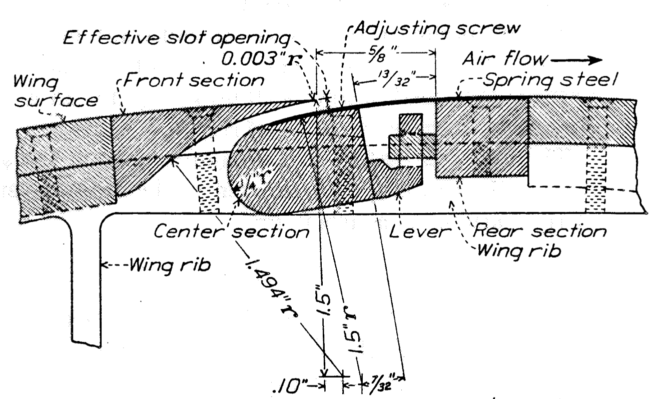

FIGURE 3.—Diagram of adjustable slot

For each slot location and opening, tests were made at "wing pressures" of −6, −2, 0, 1, 2, 6, and 12 times dynamic pressure (q). "Wing pressure" signi-

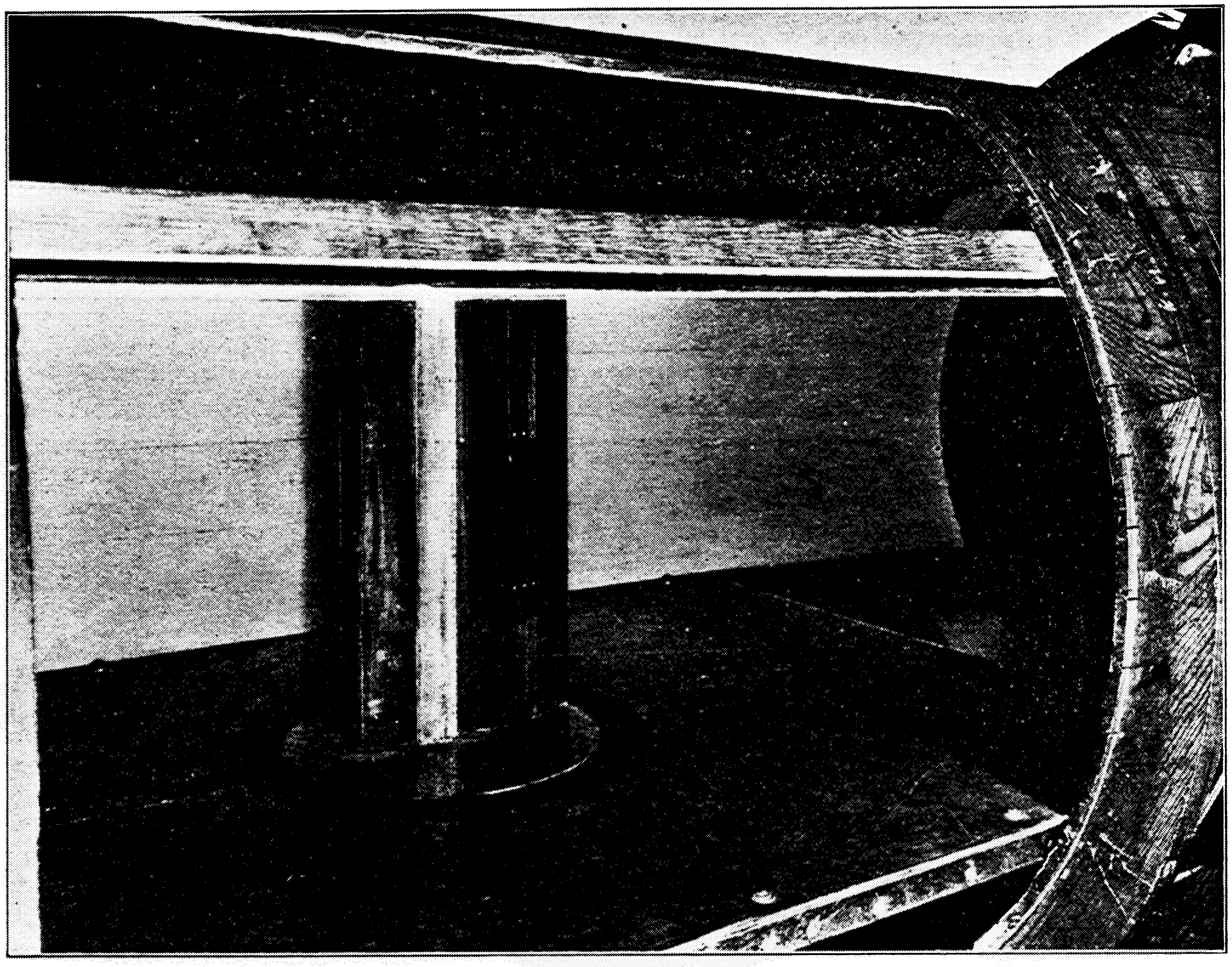

FIGURE 4.—Airfoil mounted in tunnel

fies the average pressure inside the airfoil measured with respect to the static pressure of the tunnel test section. For each slot location, opening, and wing pressure, measurements of lift, drag, and slot air quantity were made at angles of attack of -6, 0, 6, 9, 12, 15, 18, 21, 24, 27, and 30 degrees.

The dynamic pressure was held constant at 4.06 lbs. per sq. ft. during the tests. This corresponds to an average air speed of about 40 m. p. h., and an average Reynolds Number of about 445,000.

The first few tests were repeated to insure the accuracy of the results and to determine the probable errors of the various measurements.

RESULTS

The data in absolute coefficient form are given in Tables II to XVIII and a sufficient number of specimen curves are presented in Figures 6 to 26 to indicate the effect of changes in slot location, slot position, and wing pressure on certain aerodynamic characteristics and in the value of certain criteria.

The lift and drag values were reduced to absolute coefficients by the relation

$$C_L = \frac{L}{q\,S}$$

and

$$C_D = \frac{D}{q\,S}$$

where $q = \frac{1}{2}\rho V^2$ (dynamic pressure),

S = area of the airfoil,

L = measured lift,

D = measured drag.

The measured drag has been corrected for the drag of the end disks, as mentioned above. These data have not been corrected for the effect of changes in the air flow due to the partial blocking of the tunnel test section by the airfoil.

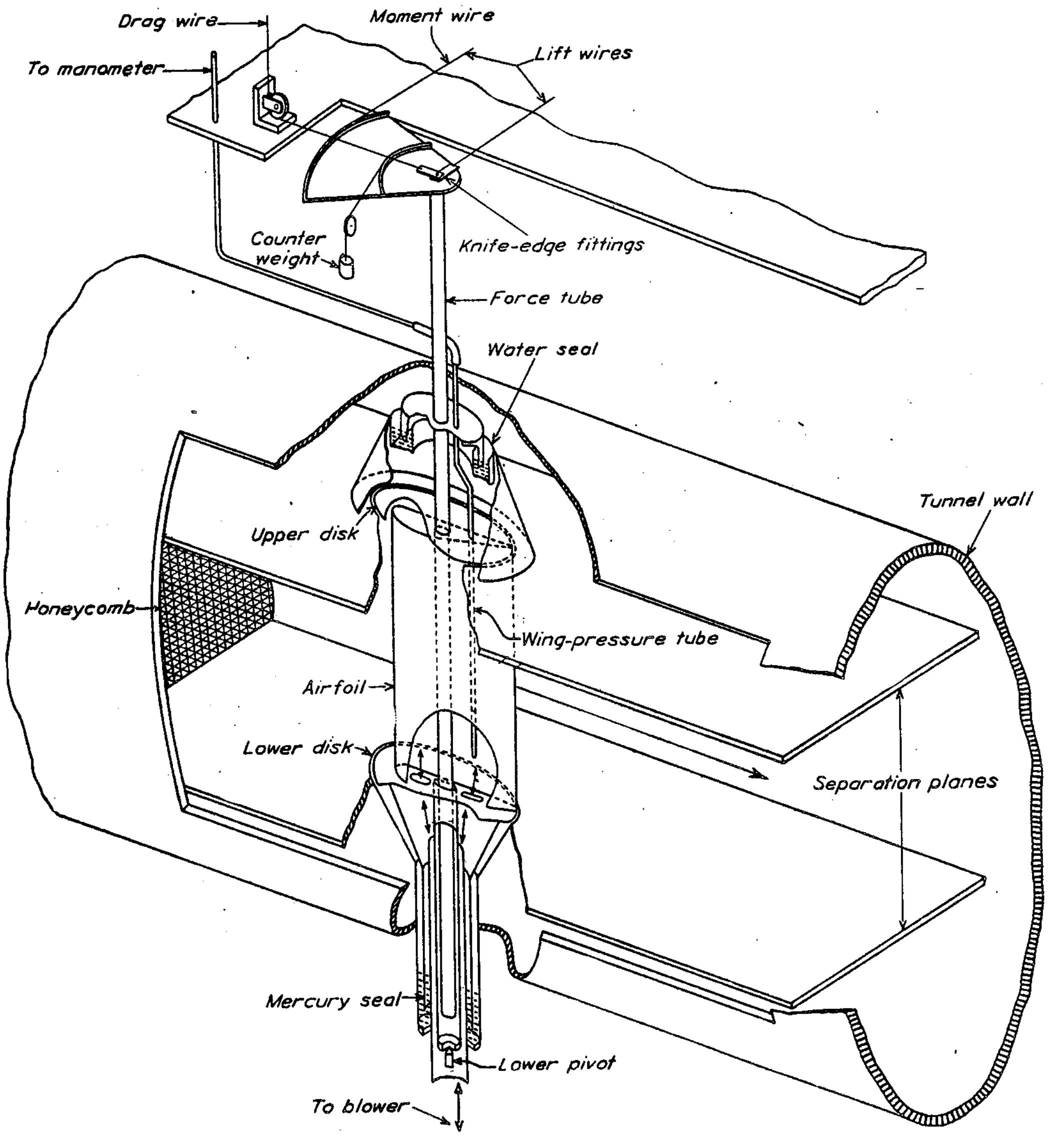

FIGURE 5.—Apparatus used for boundary layer control

The quantity of air flowing through the slot per unit time was calculated in absolute coefficient form as follows:

$$C_Q = \frac{Q}{VS}$$

where Q = quantity of air per unit time,

S = area of the wing,

V = velocity of flight (tunnel air speed).

The power required to maintain the air flow through the slot is a function of the air quantity per unit time and the wing pressure. Since this power (P_S) must be included in the total power required to propel the airplane, it is convenient to express it in terms of an equivalent drag coefficient (C_{DS}), which may be added directly to the measured drag coefficient (C_D). This coefficient is defined as follows:

$$P_S = \tfrac{1}{2} \rho S V^3 C_{DS}$$

where $C_{DS} = \frac{P}{q} \frac{Q}{VS}$

and P = wing pressure, i. e., mean static pressure inside the airfoil measured with respect to the static pressure of the tunnel test section.

Now letting $\frac{P}{q} = C_P$, which is an absolute coefficient of wing pressure,

and since $\frac{Q}{VS} = C_Q$

then $C_{DS} = C_P\, C_Q$, which is a more convenient expression.

C_{DS}, as computed above, is representative only of the power required to maintain the flow of air through the slot, and does not include the losses in the blower and duct. The actual supply system losses occurring in these tests are of no interest, and consequently no efforts were made to produce an efficient blower and duct arrangement. However, these supply losses are important in studying various possible practical applications of airfoil boundary layer control.

The probable errors in the measured results have been determined on the basis of check tests and an analysis of the balance deflections. Lift, drag, and slot air quantity were in general accurate to within ±3 per cent, and wing pressure to within ±2 per cent. The measured dynamic pressure was held constant to within ±1 per cent. The mean angle of attack error due to balance deflections was about +1 per cent, as measured from the angle of zero lift, which could be set to within ±0.1°.

DISCUSSION

Control of the boundary layer by means of air flowing in to or out of the airfoil through slots in the surface introduces certain effects, which in a practical case would appreciably modify the forces as measured on the airfoil in this investigation. An understanding of these effects and of the effects of improved flow is essential to the interpretation of the results, and an explanation is given in Appendix I. While the explanation is by no means complete, it will serve to show the nature of the more important of these effects.

The discussion of airfoil boundary layer control is divided into four parts:

A. Effect on airfoil aerodynamic characteristics.

B. Effect on certain important aerodynamic criteria of an airfoil.

C. Possible practical application to the airplane.

D. Suggestions for future research.

A. EFFECT ON AIRFOIL AERODYNAMIC CHARACTERISTICS

From the large amount of data obtained in this investigation, selections have been made to show the general manner in which the aerodynamic chacteristics of this airfoil vary with slot location, slot opening, and wing pressure. First, the effects on lift and on the effective drag coefficient (C_D+C_{DS}) are discussed (figs. 6 to 8–B), and later the changes in C_D, C_{DS}, and C_Q are studied individually (figs. 9 to 13). In general, the maximum changes were obtained with the slot located at 53.9 per cent of the chord, with a slot opening of 0.667 per cent of the chord, and with a wing pressure of $C_P=12$. For this reason each series of curves was chosen to include this condition.

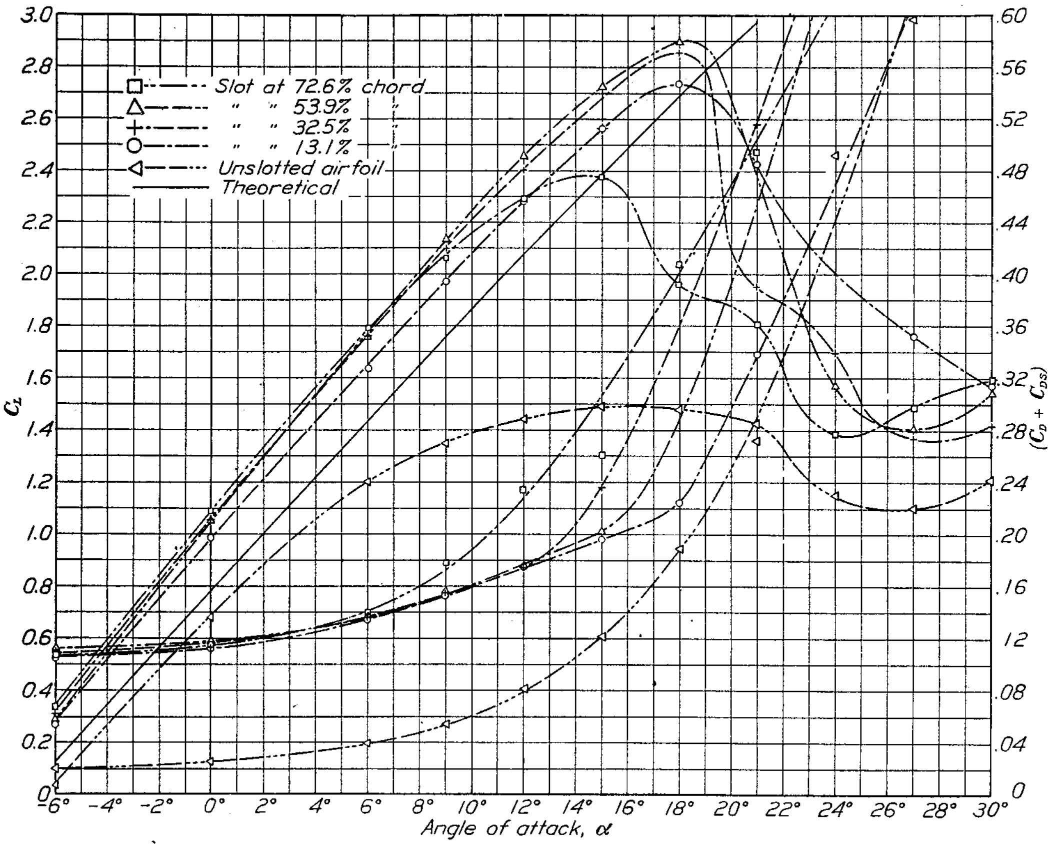

FIGURE 6.—Effect of slot position on lift and drag. Slot opening=0.667 per cent chord. $C_P=12$

Figures 6 to 8–B give the curves of lift and effective drag against angle of attack for changes in one of the above variables, and for comparison the curves for the unslotted airfoil and the calculated theoretical curves are included. The theoretical lift curve was calculated from the relation given in Reference 17, the angle of zero lift being obtained from Munk's integrals (Reference 18).

The changes in C_L obtained with the various slot locations were comparatively small. (Figure 6.) However, the best slot location depends upon the angle of attack, and a slight advantage was obtained with the slot near the trailing edge for small angles, near the midchord point for maximum lift, and near the leading edge for angles above maximum lift. The lift increases with the slot opening (fig. 7) and with wing pressure (fig. 8–A). As might be expected, these increases are fairly regular, since the energy added or the quantity of air removed from the boundary layer depends upon the slot opening and wing pressure. Boundary layer control decreases the angle of attack for zero lift, and in general increases the angle of maximum lift.

At the small angles of attack and low wing pressures, as indicated in Figure 8–A, when $C_P=0$ and 1, the lift coefficient, as compared to that for the plain airfoil, is reduced, while at the larger angles it is increased.

The effect of changing the angle of attack and wing pressure on the measured drag coefficient, (C_D,) is shown in Figure 9 for one slot location and opening. This combination gives the maximum decrease in measured drag obtained within the limits of this investigation. The other slot locations and slot openings give the same general type of curves. The increased drag when C_P is negative and the decreased and negative drag when C_P is positive are due to the reaction of the air being accelerated as it flows in or out through the slot. This reaction is explained and is included in

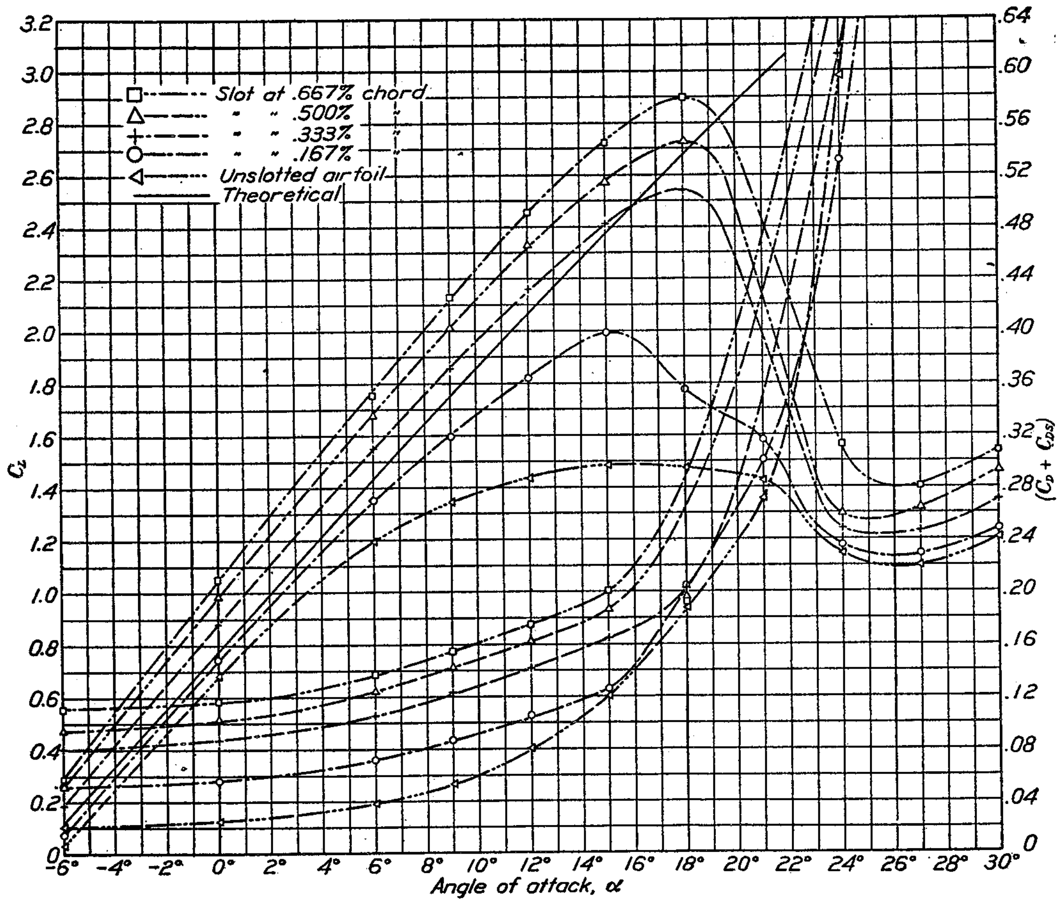

FIGURE 7.—Effect of slot width on lift and drag. Slot at 53.9 per cent of chord from L. E. $C_P=12$

This reversal is due to the effect of the comparative velocities of the air flowing over the slot and that flowing from it. The velocity of the air from the slot is about constant for all angles of attack, and the velocity of the air flowing over the slot is less at the higher angles of attack. The boundary layer is increased and lift decreased by the addition of the slow moving air at small angles, while at large angles the added air has higher velocity which accelerates the boundary layer and increases the lift. The increase in C_L at the large angles of attack, with no air flow through the slot, may be due to the change in profile or to the slot retarding the air flowing forward over the upper surface.

equations (1) and (2) of Appendix I. Comparatively small changes in the drag are also produced by the improved air flow over the airfoil and by the presence of the slot.

Figures 10 and 11 show the change in the equivalent drag coefficient (C_{DS}) and the slot air quantity coefficient (C_Q) against wing pressure (C_P) for one slot location and all slot openings. The variation in C_Q and C_{DS} with angle of attack is small, and $-6°$ and 15° angles of attack were chosen because in general they gave the maximum and minimum values for a given slot location. The differences between these maximum and minimum values with angle of attack are greater for slots located nearer to the leading edge than those

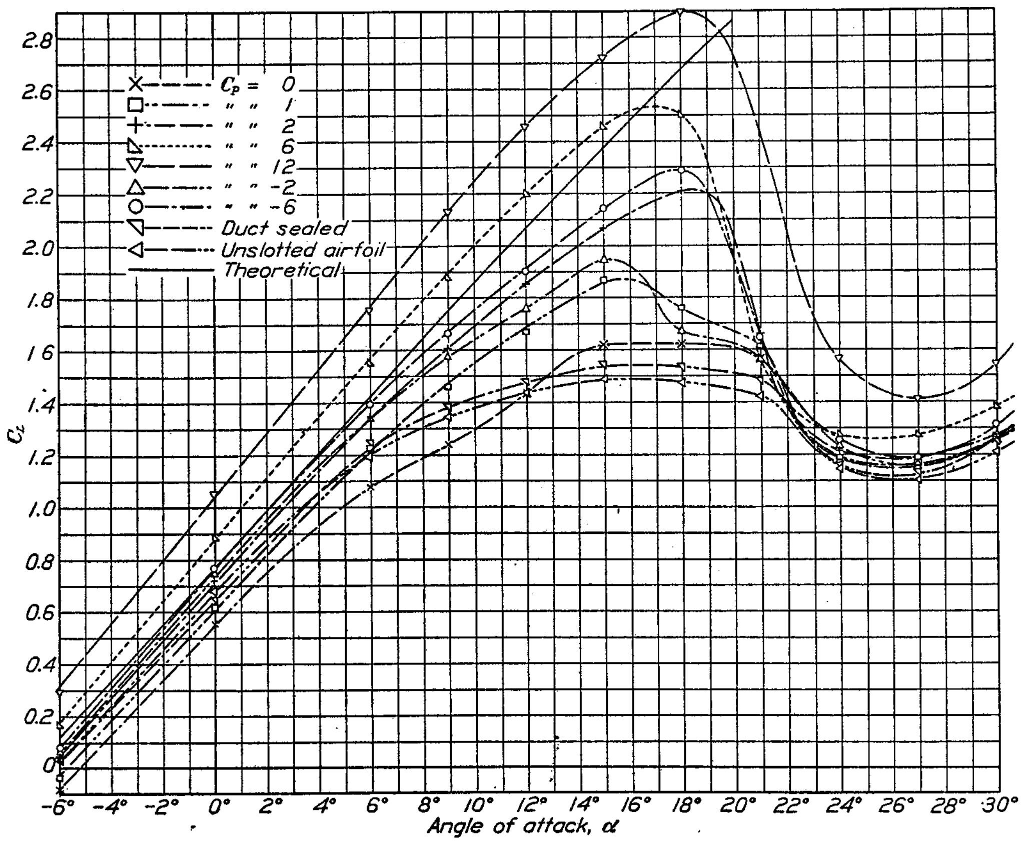

FIGURE 8-A.—Effect of wing pressure on lift. Slot at 53.9 per cent of chord from L. E., slot open 0.667 per cent of chord

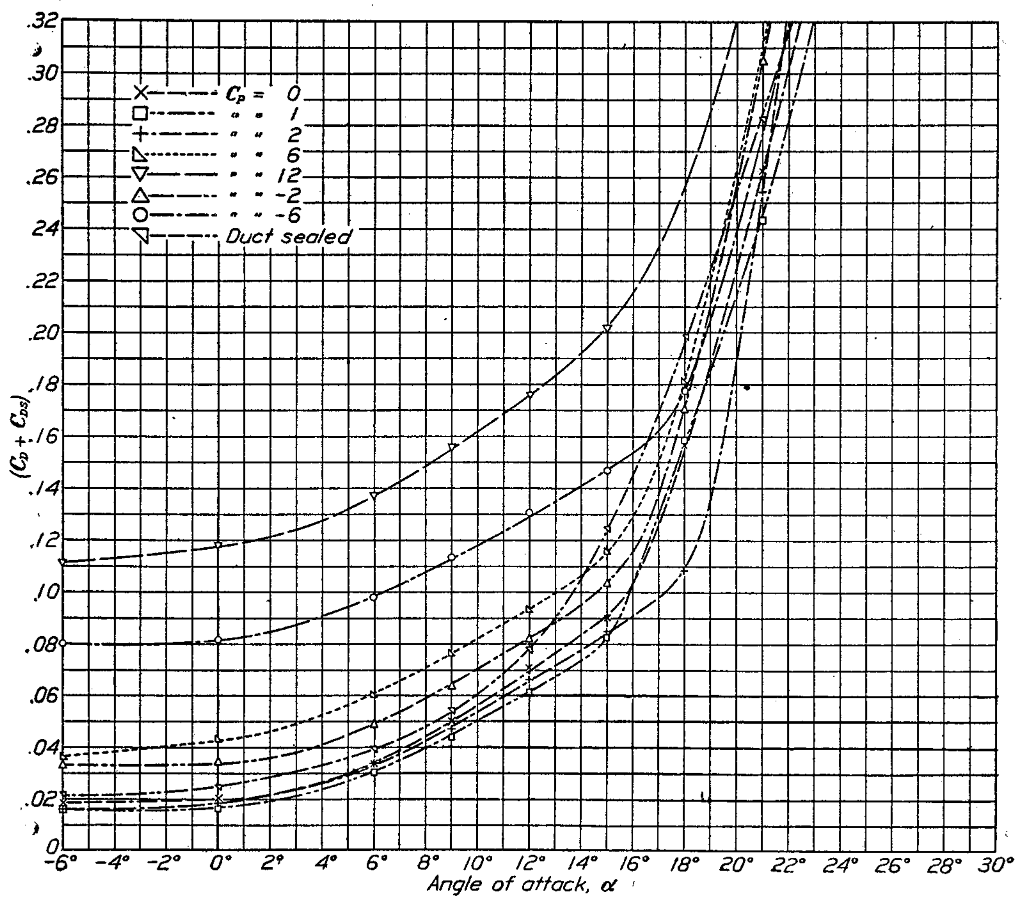

FIGURE 8-B.—Effect of wing pressure on drag. Slot at 53.9 per cent chord from L. E., slot open 0.667 per cent chord

shown in Figures 10 and 11. These curves may be represented by equations in which

$$C_Q = K\,S_S\,(C_P - C_{P0})^{\frac{1}{2}}$$

and

$$C_{DS} = K\,S_S\,C_P\,(C_P - C_{P0})^{\frac{1}{2}}$$

where C_{P0} is the value of C_P when C_Q is zero, and is due to the local static pressure on the upper surface of the airfoil at the slot, S_S is the area of the slot opening, and K is determined by experiment. The numerical value of K and the algebraic sign of $(C_P - C_{P0})$ change with a change in direction of the air flow through the slot,

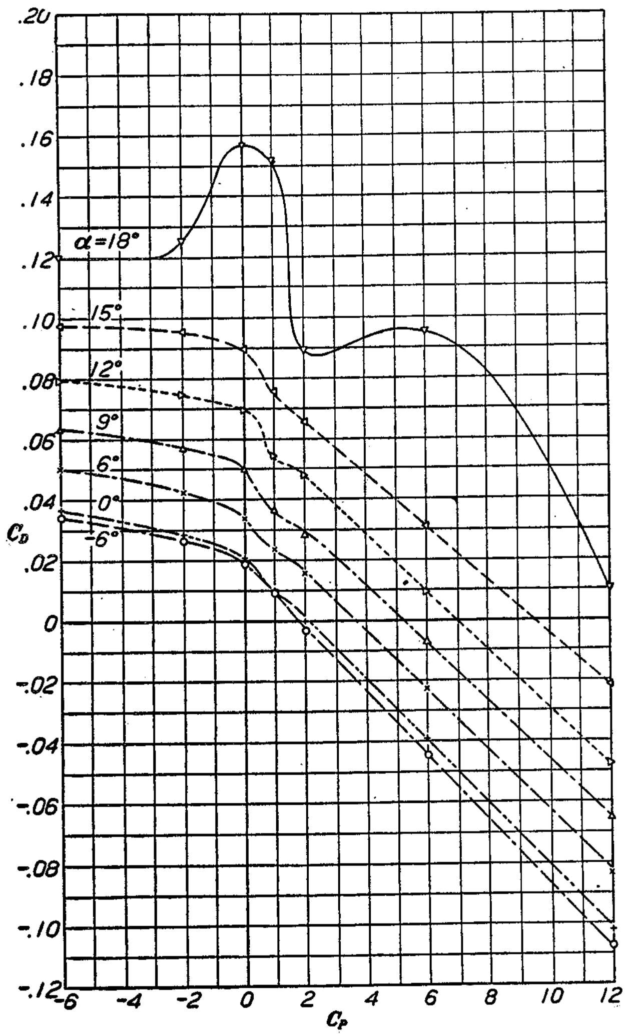

FIGURE 9.—Effect of wing pressure on measured drag. Slot at 53.9 per cent of chord from L. E. Slot open 0.667 per cent chord. C_D vs. C_P

with the slot location and opening, and only slightly with the angle of attack. The relationship between C_{DS} and C_Q with changes in slot location and opening is shown in Figure 12, for $\alpha = -6°$ and $C_P = 1$; and in Figure 13, for $\alpha = 15°$ and $C_P = 12$. As will be explained later, Figure 12 represents the best condition for high speed and Figure 13 for low speed of an airplane with boundary layer control. These changes are due to the changes in pressure at the slot and in the air flow over it for each slot location. The relationship between C_{DS} and C_Q in Figures 12 and 13 may be seen from the above expressions for these two quantities.

For the conditions represented by Figures 6, 7, and 8–B, the large values of $(C_D + C_{DS})$ are due chiefly to C_{DS}, as shown in Figure 10. In Figure 8–B the large

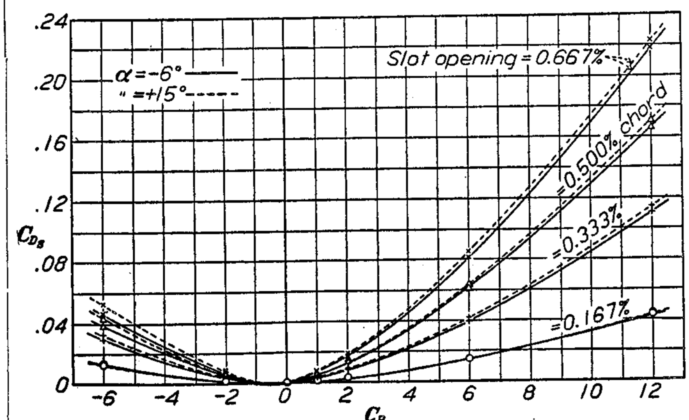

FIGURE 10.—Change in C_{DS} due to various slot openings and wing pressures. Slot at 53.9 per cent chord from L. E.

differences in $(C_D + C_{DS})$ for the same values of $+C_P$ and $-C_P$ are due to the magnitude and direction of the reaction produced by the air flowing in or out through the slot. The reactions are explained in equations (11) and (13) of Appendix I. When $C_P = 0$ there is a slight reduction in $(C_D + C_{DS})$ since $C_{DS} = 0$, and there

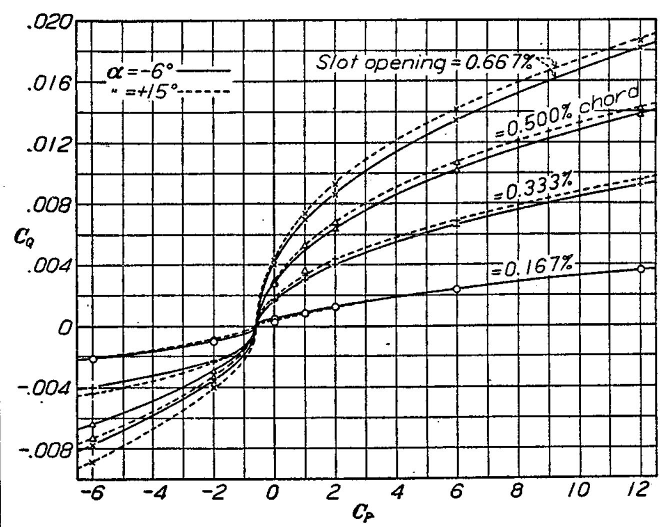

FIGURE 11.—Change in C_Q due to various slot openings and wing pressures. Slot at 53.9 per cent chord from L. E.

is a jet reaction produced by the small quantity of air flowing out through the slot. (See fig. 11.)

B. EFFECT ON CERTAIN IMPORTANT AERODYNAMIC CRITERIA OF AN AIRFOIL

There are certain airfoil aerodynamic factors which form important criteria by which the effects of the various combinations of slot locations, slot openings, and wing pressures may be compared. A criterion for wing area and stalling speed is $C_{L\ maximum}$, for high speed $C_{D\ minimum}$, and a figure of merit for over-all effectiveness is given by $\frac{C_{L\ maximum}}{C_{D\ minimum}}$. The general manner in which the criteria vary with the various slot conditions is indicated in Figures 14 to 25.

Figures 14 to 19 give the percentage increase in $C_{L\ maximum}$ as compared to the unslotted airfoil for the various combinations of slot locations, slot openings,

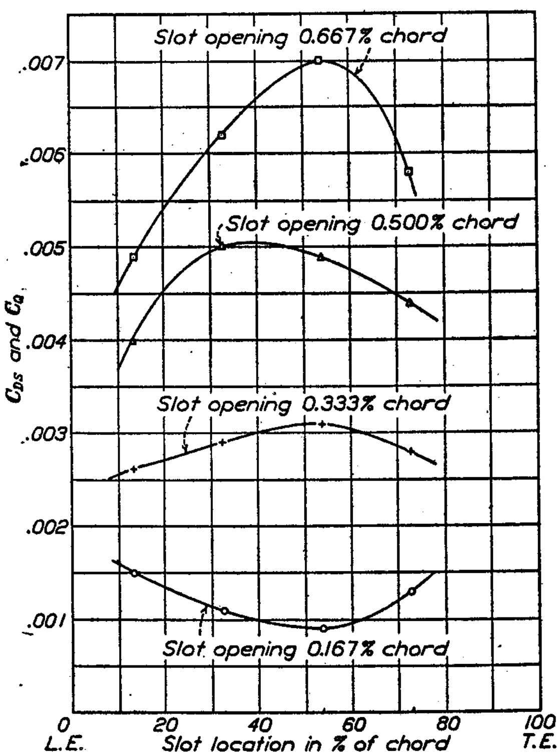

FIGURE 12.—Change in C_{DS} and C_Q with various slot openings and slot locations. $\alpha=-6°$. $C_P=1$

and wing pressures. The slot location at 53.9 per cent of the chord from the leading edge, gave the maximum increase in $C_{L\ maximum}$ (figs. 14 and 15), although a slot located as far forward as 25 per cent and as far back as 60 per cent of the chord would appear to give nearly as good results. The percentage increase in $C_{L\ maximum}$ with slot opening and wing pressure is shown in Figures 16 to 19. The dashed part of the curves in Figures 18 and 19 represents estimated values. Within the limits of this investigation, the above figures indicate that a further increase in $C_{L\ maximum}$ could be obtained with larger slot openings or higher wing pressures, or both. However, there is a decrease in the rate at which $C_{L\ maximum}$ increases with the slot opening and wing pressure.

In order to compare the drag of the unslotted airfoil with that of the airfoil with boundary layer control, the power required to deliver air to the slots must be taken into account. As explained before, this power can be computed from C_{DS} which is directly comparable with C_D. Hence, for the unslotted airfoil C_D, and for the airfoil with boundary layer control, C_D+C_{DS} are on a fair basis for comparison. The profile drag coefficient for high speed is not materially different from $C_{D\ minimum}$. At least, similar airfoils will maintain about the same difference throughout this range of small lift coefficients. Therefore, a comparison of $C_{D\ minimum}$ and $(C_D+C_{DS})_{minimum}$ will indicate the relative merits for high speed of the airfoil with boundary layer control as compared with the unslotted airfoil.

The manner in which (C_D+C_{DS}) at $\alpha=-6°$ varies with wing pressure is shown in Figures 20 and 21, and the minimum values lie between $C_P=0$ and $C_P=2$, depending upon the slot opening and slot location. Since, in general, the minimum values were obtained at $\alpha=-6°$, this angle was chosen to represent the minimum drag coefficient for all slot conditions. The minimum values for each slot opening and slot location were taken from the test data and were plotted in terms of percentage variation from the minimum drag of the unslotted airfoil against slot opening and slot location in Figures 22 and 23. These figures indicate that the minimum drag would continue to decrease as

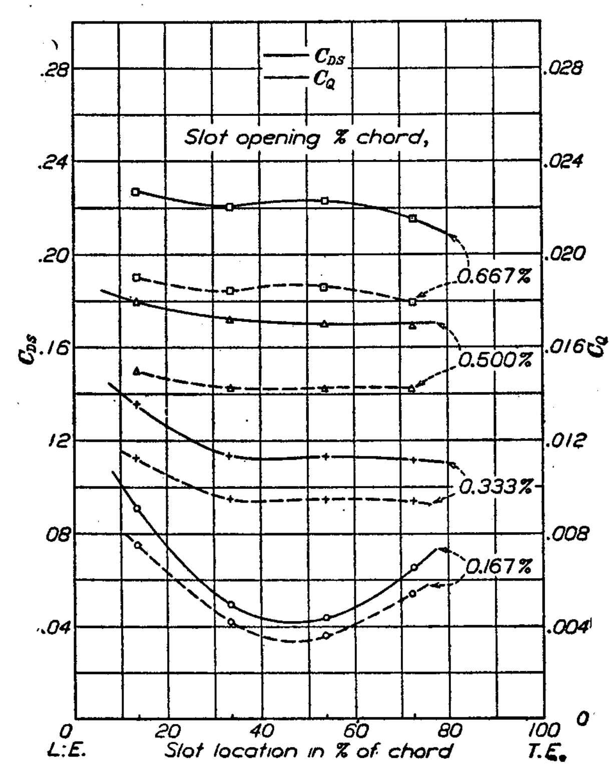

FIGURE 13.—Changes in C_{DS} and C_Q with various slot openings and slot locations. $\alpha=15°$. $C_P=12$

the slot is moved back along the chord or as the slot opening is increased.

Since $C_{L\ maximum}$ represents the low speed condition and $(C_D+C_{DS})_{minimum}$ the high speed condition, the larger the value of the ratio $\frac{C_{L\ maximum}}{(C_D+C_{DS})_{minimum}}$ the greater the speed range possible and the better the airfoil for general purposes. This criterion is practically independent of aspect ratio. The percentage change in $\frac{C_{L\ maximum}}{(C_D+C_{DS})_{minimum}}$ as compared with that obtained for the unslotted airfoil is plotted against slot location and wing pressure in Figures 24 and 25.

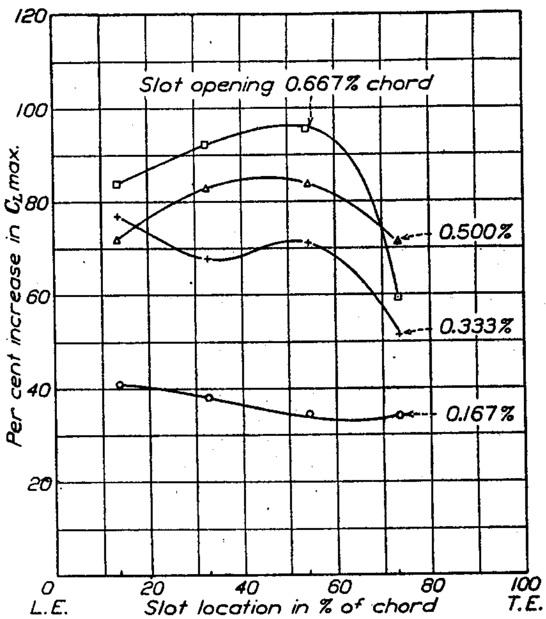

FIGURE 14.—Increase in maximum lift due to the slot at various locations and openings. $C_P=12$

In the above ratios, in every case the value of $C_{L\ maximum}$ was obtained with the highest wing pressure used (12 times the dynamic pressure); for the condition of $(C_D+C_{DS})_{minimum}$ the wing pressure was approximately

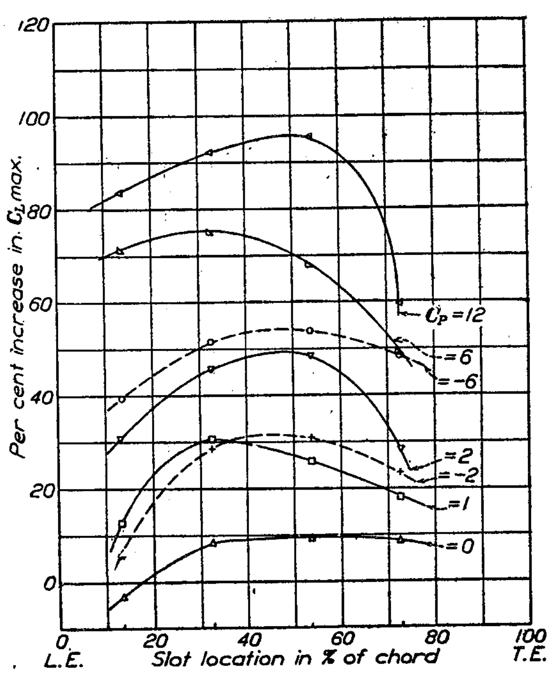

FIGURE 15.—Increase in maximum lift due to various wing pressures and slot locations. Slot opening 0.667 per cent chord

equal to the dynamic pressure. The values of $(C_D+C_{DS})_{minimum}$ were obtained from the faired curves in Figures 22 and 23. The maximum increase in the above ratio was obtained with the widest slot located at 53.9 per cent of the chord from the leading edge.

C. POSSIBLE PRACTICAL APPLICATION TO THE AIRPLANE

It is recognized that the application of boundary layer control to an airplane presents several practical

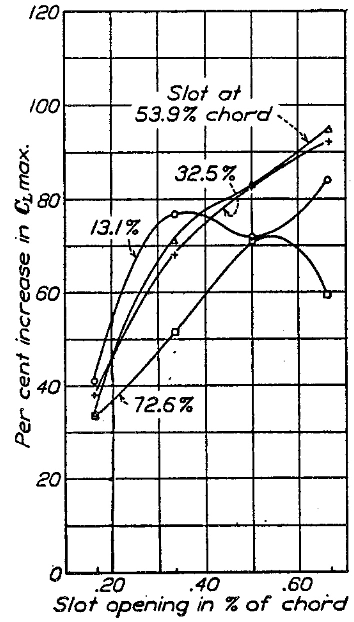

FIGURE 16.—Increase in maximum lift due to various slot openings and slot locations. $C_P=12$

problems, such as provision of a reliable source of power for the blower and development of the blower

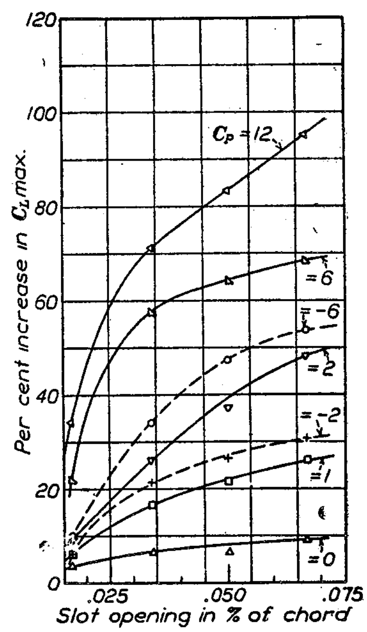

FIGURE 17.—Increase in maximum lift due to various slot openings and wing pressures. Slot at 53.9 per cent chord from L. E.

and air ducts. These problems will not be discussed in this report. However, it is interesting to consider some of the advantages which appear possible from the

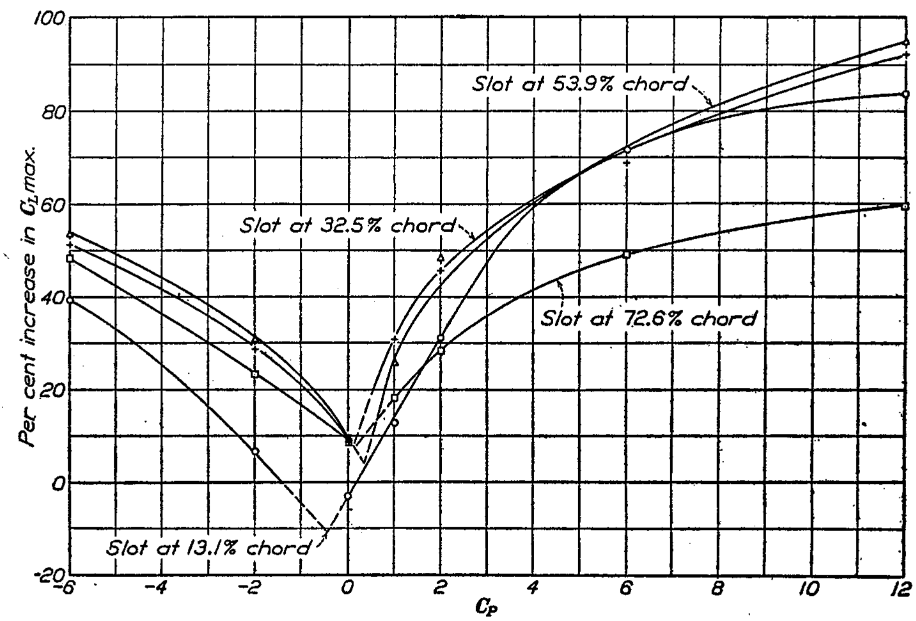

FIGURE 18.—Increase in maximum lift due to various wing pressures and slot locations. Slot opening 0.667 per cent chord

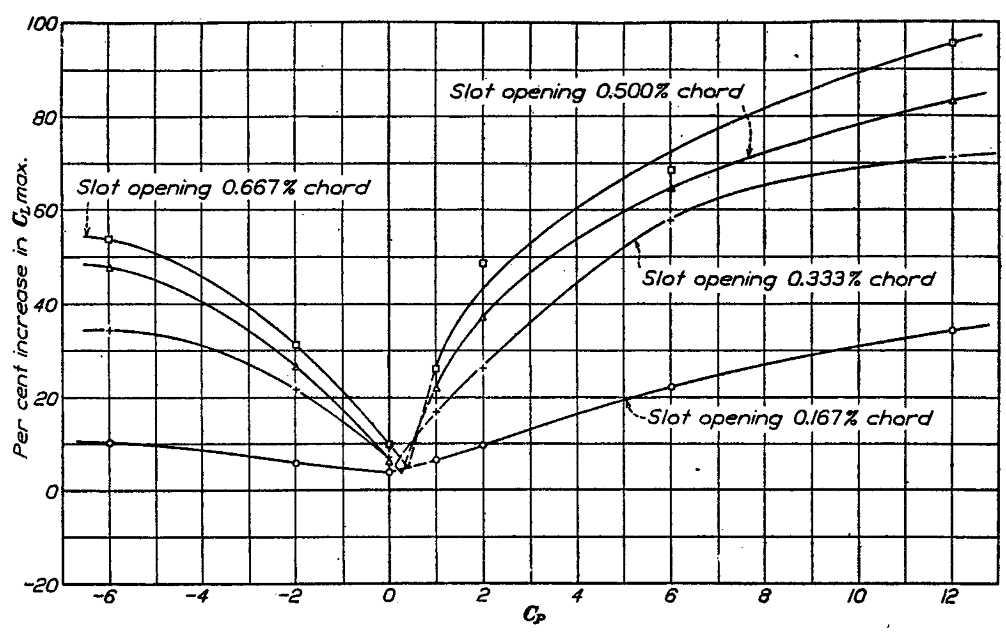

FIGURE 19.—Increase in maximum lift due to various wing pressures and slot openings. Slot at 53.9 per cent chord from L. E.

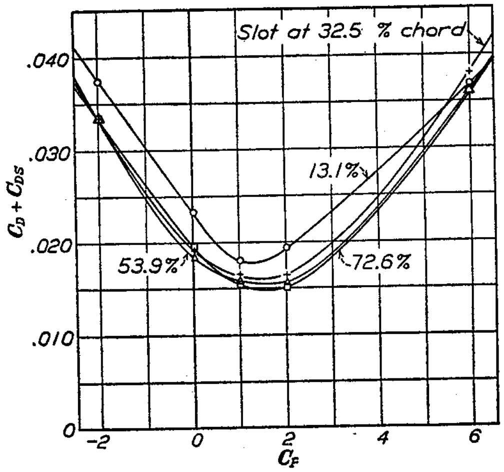

FIGURE 20.—Change in minimum drag due to various slot locations and wing pressures. Slot opening, 0.667 per cent chord. $\alpha=-6°$

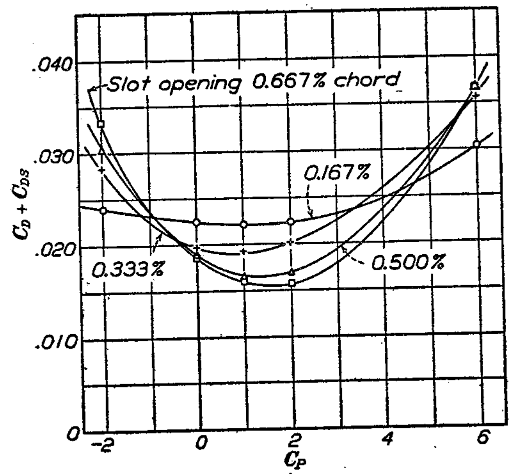

FIGURE 21.—Change in minimum drag due to various slot openings and wing pressures. Slot at 53.9 per cent chord from L. E. $\alpha=-6°$

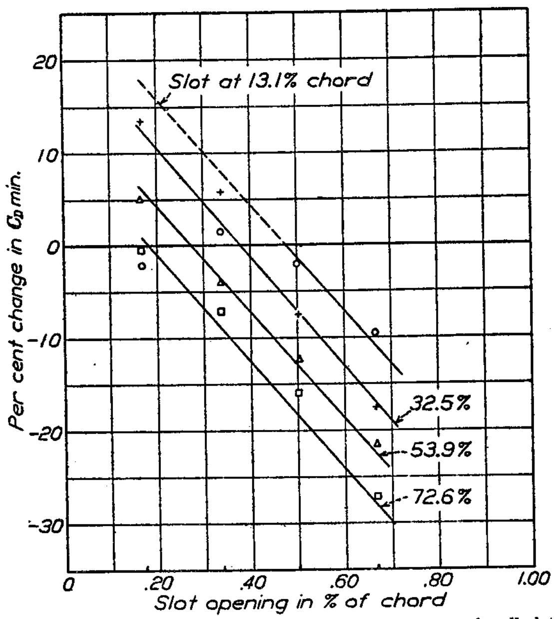

FIGURE 22.—Percentage change in (C_D+C_{DS}) minimum for all slot openings and slot positions

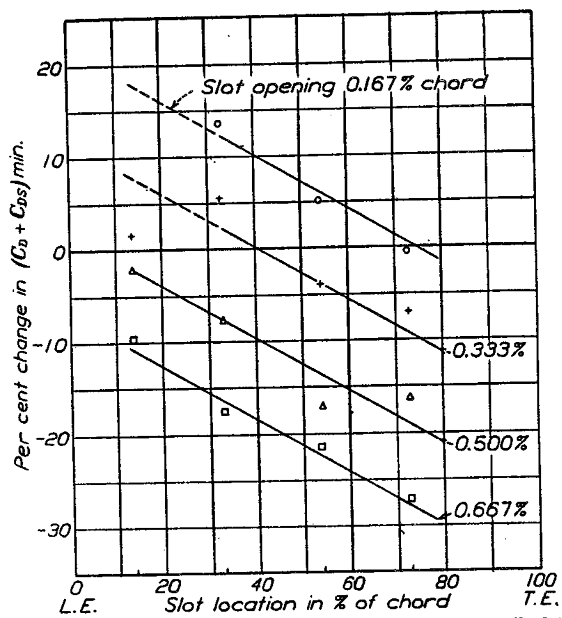

FIGURE 23.—Percentage change in (C_D+C_{DS}) minimum for all slot locations and openings

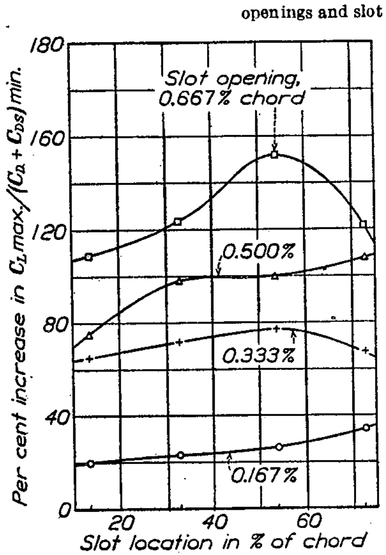

FIGURE 24.—Percentage increase in $\frac{C_{L\,max.}}{(C_D+C_{DS})_{min.}}$ due to slot opening and slot location. $C_P=12$ for C_L maximum. C_P=approximately 1 for (C_D+C_{DS}) minimum.

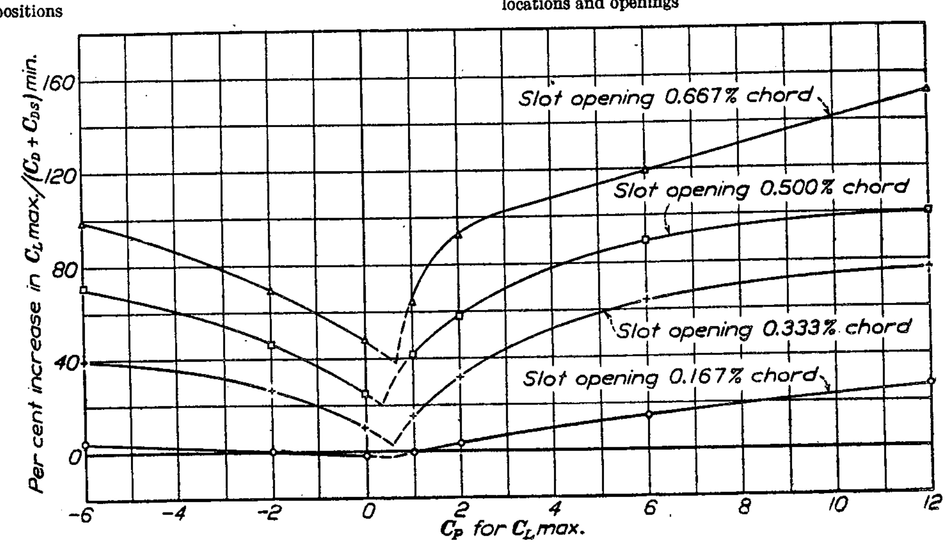

FIGURE 25.—Percentage increase in $\frac{C_{L\,max}}{(C_D+C_{DS})_{min.}}$ due to slot opening. C_P=approximately 1 form (C_D+C_{DS}) minimum. Slot at 53.9 per cent chord

results of this investigation. To show these advantages, a comparison will be made between an airplane with and without boundary layer control.

To form a fair basis of comparison, in each case, the total weight of the airplane (including the weight of air ducts and blowers) and also the motive power are considered constant; the efficiency of the air ducts and blower is assumed the same as that of the propeller; and the parasite drag coefficient is constant. Also, it is assumed that the air which flows out through the slot has been accelerated up to the velocity of flight by the engine, fuselage, or other parts of the airplane. That is, a condition corresponding more nearly to those under which the tests were made would be

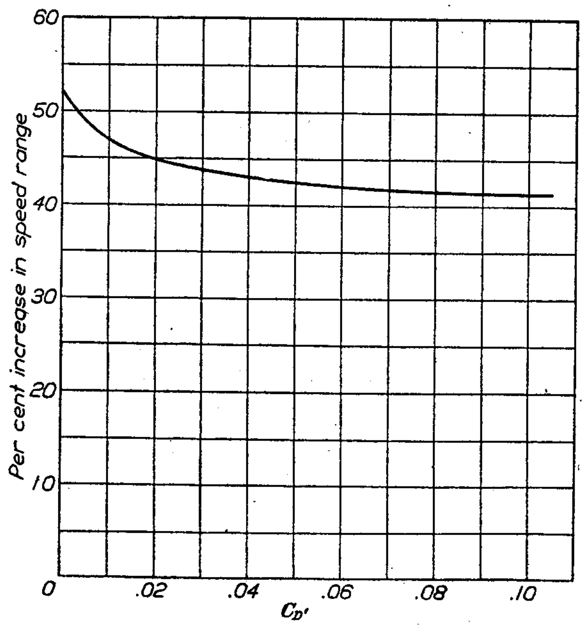

FIGURE 26.—Percentage increase in speed range with slot at 53.9 per cent chord from L. E., slot open 0.667 per cent chord

realized by taking the air into the wing from burbled regions about the airplane, or the exhaust gases may be used. It is also important to understand the relation between the engine power required to drive the propeller (P_p) and that for the blower (P_S) which is given by the equations:

$$P_p = \tfrac{1}{2}\rho S V^3 \frac{C_D}{\eta_p}$$

and

$$P_S = \tfrac{1}{2}\rho S V^3 \frac{C_{DS}}{\eta_S}$$

where η_p is the efficiency of the propeller and η_s is the efficiency of the duct and blower systems. If $\eta = \eta_p = \eta_s$, as is assumed above, then, if the engine drives the blower as well as the propeller, the total power required is given by the relation

$$P = \tfrac{1}{2}\rho S V^3 \frac{(C_D + C_{DS})}{\eta}$$

Since the speed range of an airplane is an indication of its aerodynamic efficiency, it is possible to indicate the effectiveness of boundary layer control by the ratio of the approximate speed range ratios for the unslotted and slotted wing of the same area. The above ratio is given by the following equation:

$$\frac{\dfrac{V_{Hs}}{V_{Ls}}}{\dfrac{V_{Hp}}{V_{Lp}}} = \sqrt[2]{\frac{(C_L)_{s\ maximum}}{(C_L)_{p\ maximum}}}\ \sqrt[3]{\frac{(C_D)_{p\ minimum} + C_{D'}}{(C_D + C_{DS})_{s\ minimum} + C_{D'}}}$$

where the subscripts p and s represent the unslotted wing and the wing with boundary layer control, respectively, V_L and V_H represent the low and high speed for the particular condition. C_D' is representative of the parasite drag of the airplane which, in each case, is given by $\tfrac{1}{2}\,\rho\, S\, V^2\, C_D'$, where S is the area of the plain wing. The induced drag of the airplane is not included in the above equation because it depends upon the actual speed range and aspect ratio of the particular airplane, which are of no particular importance in this discussion.

An example of the numerical values of the above ratio is shown plotted against C_D' in Figure 26. The lift and drag coefficients for this example were taken for the same condition which gave the maximum increase in the ratio $\dfrac{C_{L\ maximum}}{(C_D + C_{DS})_{\ minimum}}$ (See figs. 24 and 25.)

The maximum value of the ratio of speed range ratios possible with the same wing area and within the limits of this investigation is shown on the curves where C_D' is zero. This value may be increased by the use of higher wing pressures and/or larger slot openings.

Another feature of boundary layer control is that it appears possible to improve the lateral control of airplanes as compared with that obtained with the conventional ailerons. Since the lift increases with the wing pressure (fig. 8–A) a rolling moment about the longitudinal axis may be produced by increasing the wing pressure on the outer portion of one wing and decreasing it on the other. Also, since for a given value of C_P the difference between lift coefficients obtained with air flowing through the slot and with no flow increases with the angle of attack up to and slightly above the stall, good lateral control apparently could be obtained at low flying speeds. The conventional ailerons may give a yawing moment due to the difference in drag on the wings which, if not balanced by the rudder, may also produce a rolling moment opposing that of the airlerons. These moments are of importance only in stalled flight where the yawing moments and the rolling moments due to sideslip become large, and where, due to the low air speed, the effectiveness of the rudder is reduced. With boundary layer control the drag could be reduced (fig. 9) so that the yawing moment would be very small, or it might be made to act in the direction to aid the rolling moment. In this case, if the air which flows out through the slot is taken into the wing in the plane of symmetry, the values for the measured drag coefficient may be taken directly from the data.

Another interesting feature, which is indicated by the results of this investigation, is the possibility of jet propulsion by utilizing the propulsive force produced by air flowing out of a backward-opening slot. To accomplish this, the negative measured drag as determined from these tests must be made equal to or greater than the sum of the induced and parasite drags of the airplane, in order to obtain level flight or acceleration and climb. Owing to the large quantity of air required, it would have to be replenished from the undisturbed atmosphere and in accordance with the development of equation (17), Appendix I, the value of C_D given in the data and in Figure 9 would be increased by $2C_Q$ and the value of C_{DS}, diminished by C_Q. However, the efficiency of jet propulsion, as obtained by this method of boundary layer control, can never be very high unless the supply of air which flows out through the slot is carried along in the airplane and the velocity of flight is very much higher than is obtained at present. This is due to the fact that the efficiency of a jet for propulsion is a maximum when the velocity of discharge is equal to the velocity of motion, and in order that the mass of air which would be carried along in the airplane would not be excessive, the discharge velocity necessarily would be very high.

The results obtained on a model in a wind tunnel are not always realized when applied to a full-scale airplane. However, some of the causes of discrepancies are known and allowances, some of which are indicated below, may be made to bring the results into closer agreement.

In accordance with Reference 17, page 20, the equivalent of infinite aspect ratio should have been obtained, since the model was tested in a closed-throat tunnel and it extended entirely across the tunnel. (See fig. 4.) The slope of the lift curve, $\left(\frac{dC_L}{d\alpha},\right)$ as obtained for the unslotted airfoil in these tests (fig. 7) is about 0.106 as compared with 0.096, given in Reference 19, for corrected wind-tunnel tests, and with 0.1096, which is given by theory for an inviscid fluid.

The scale effect on C_L and C_D is probably large owing to the comparatively low Reynolds Number of 445,000, and furthermore the effects produced by boundary layer control may change with the scale. The scale effect on C_Q and C_{DS} is comparable to that for the flow of air through orifices.

D. SUGGESTIONS FOR FUTURE RESEARCH

The analysis of the present data presents several suggestions for extension of the tests. Some of these tests had been planned and were considered important in this investigation, but were not made because of the limited time available.

It is believed from these and former tests (Reference 9) that the beneficial effects of boundary layer control may be more economically obtained by the following methods:

1. Airfoils with high camber ratios or flaps would probably give higher lift coefficients for the same expenditure of slot power than the airfoil used in these tests. A thick, high-cambered airfoil with a well-rounded leading edge probably would give better results than the high-cambered thin or medium thick sections (especially with regard to lower minimum drag).
2. Larger slot openings would probably give higher lift coefficients and lower drag coefficients for the same expenditure of slot power than were obtained in these tests.
3. The best slot locations for increasing the lift are fairly well determined, but a slot located nearer to the trailing edge than any of those tested in this investigation would probably give a lower minimum drag. Multiple slots with the air flowing in or out through the slot, or both, would probably give the best results (especially higher maximum lift coefficients).

Since, as mentioned before, the results obtained on a model in a wind tunnel are not always realized when applied to full-scale airplanes, the scale effect, as well as the effect of aspect ratio, should be investigated with boundary layer control.

CONCLUSIONS

1. The maximum lift of an airfoil may be greatly increased by removing the boundary layer or by accelerating it by jet action.
2. Within the limits of this investigation and at any given angle of attack below maximum lift, the lift coefficient increases with the quantity of air flowing through the slot per unit of time, i. e., with increases in slot opening or wing pressure.
3. The lift coefficient apparently continues to increase with the quantity of air flowing out through the slot; while with the air flowing in through the slot, the lift coefficient apparently approaches, as a maximum, the value obtained by theory for an inviscid fluid.
4. The drag coefficient of an airfoil, under the conditions of these tests, may be appreciably decreased.
5. Improved lateral control in stalled flight and greater speed ranges of airplanes appear possible by the use of this form of boundary layer control.

REFERENCES

1. Handley Page, F.: Tests on an Airfoil with Two Slots Suitable for an Aircraft of High Performance. N. A. C. A. Technical Memorandum No. 369 (1926).
2. Lachmann, G., Wieselsberger, C., Katzmayr, R., and Kirste, L.: Experiments with Slotted Wings. N. A. C. A. Technical Note No. 71 (1921).

3. Lachmann, G.: Results of Recent Experiments with Slotted Wings. N. A. C. A. Technical Memorandum No. 298 (1925).
4. Fales, E. N., and Kerber, L. V.: Tests of Pneumatic Means for Raising Airfoil Lift and Critical Angle. Journal of the Society of Automotive Engineers, May, 1927, pp. 575–581.
5. Seewald, F.: Increasing Lift by Releasing Compressed Air on the Suction Side of Airfoil. N. A. C. A. Technical Memorandum No. 441 (1927).
6. Wieland, K.: Experiments with a Wing from which the Boundary Layer is Removed by Pressure or Suction. N. A. C. A. Technical Memorandum No. 472 (1928).
7. Perring, W. G. A., and Douglas, C. P.: Wind Tunnel Experiments on the Effect on the Maximum Lift of Withdrawing and Discharging Air from the Upper Surface of an Airfoil. British A. R. C. Reports and Memoranda No. 1100 (Ae. 278). April, 1927.
8. Katzmayr, R.: Wings with Nozzle-Shaped Slots. N. A. C. A. Technical Memorandum No. 521 (1929).
9. Reid, E. G., and Bamber, M. J.: Preliminary Investigation on Boundary Layer Control by Means of Suction and Pressure with the U. S. A. 27 Airfoil. N. A. C. A. Technical Note No. 286 (1928).
10. Wolff, E. B.: Preliminary Investigation of the Effect of a Rotating Cylinder in a Wing. N. A. C. A. Technical Memorandum No. 307 (1925).
11. Wolff, E. B., and Koning, C.: Tests for Determining the Effect of a Rotating Cylinder Fitted into the Leading Edge of an Airplane Wing. N. A. C. A. Technical Memorandum No. 354 (1926).
12. Ackeret, J., Betz, A., and Schrenk, O.: Experiments with an Airfoil from which the Boundary Layer is Removed by Suction. N. A. C. A. Technical Memorandum No. 374 (1926).
13. Schrenk, O.: Experiments with a Sphere from which the Boundary Layer is Removed by Suction. N. A. C. A. Technical Memorandum No. 388 (1926).
14. Ackeret, J.: Removing Boundary Layer by Suction. N. A. C. A. Technical Memorandum No. 395 (1927).
15. Schrenk, O.: Experiments with a Wing Model from which the Boundary Layer is Removed by Suction. N. A. C. A. Technical Memorandum No. 534 (1929).
16. Knight, Montgomery, and Bamber, M. J.: Wind Tunnel Tests on Airfoil Boundary Layer Control Using a Backward Opening Slot. N. A. C. A. Technical Note No. 323 (1929).
17. Prandtl, L.: Applications of Modern Hydrodynamics to Aeronautics. N. A. C. A. Technical Report No. 116 (1921).
18. Munk, Max M.: The Determination of the Angles of Attack of Zero Lift and of Zero Moment, Based on Munk's Integrals. N. A. C. A. Technical Note No. 122 (1923).
19. Higgins, G. J.: The Prediction of Airfoil Characteristics. N. A. C. A. Technical Report No. 312 (1929).

APPENDIX I

STUDY OF THE FORCES INTRODUCED BY BOUNDARY LAYER CONTROL

Control of the boundary layer, by means of air flowing into or out of the airfoil through slots in the surface, introduces certain effects, which, in a practical case, would appreciably modify the forces as measured on the airfoil in this investigation. The following explanation, which is by no means complete, is given to show the approximate nature of these effects, as well as the effect of improved air flow.

To illustrate the principle by which the forces, due to boundary layer control, are produced, assume a hollow airfoil and a suitable blower inside to maintain the pressure differences so that air flows in one opening in the surface and out another. It is assumed that the volume of the air space inside the airfoil is large in comparison to the openings, so that the air velocity inside may be considered zero. If the airfoil be moved in a straight line at a velocity (V), the air taken in must be accelerated up to this velocity by an increment of velocity represented by $\Delta\nu_1$, and the process produces a force on the airfoil.

Now consider the forces produced by the air flowing out of the airfoil. If the air flows out in the form of a jet, a reaction is produced on the airfoil by the air being accelerated by an increment of velocity $(\Delta\nu_2)$. Its force acts along the axis of the jet and is independent of the motion of the airfoil.

The expressions from which the above forces may be computed are derived as follows:

Force = mass × acceleration.

$$= m\frac{\Delta\nu}{T}$$

$$R_1 = \frac{m\Delta\nu_1}{T} \qquad -R_2 = \frac{m\Delta\nu_2}{T}$$

$$= \rho Q\Delta\nu_1 \qquad = \rho Q\Delta\nu_2$$

where R_1 = force produced by the air flowing in through the opening,

R_2 = force produced by the air flowing out through the opening,

and $\rho Q = \frac{m}{T}$ = mass of air which flows through the airfoil per unit time,

reducing to coefficient form,

$$C_{R_1} = \frac{\rho Q\Delta\nu_1}{\frac{1}{2}\rho SV^2}$$

$$= \frac{2Q\Delta\nu_1}{SV^2}$$

since $\qquad Q = C_Q VS$

then $\qquad C_{R_1} = 2C_Q\frac{\Delta\nu_1}{V} \qquad (1)$

and similarly $\qquad C_{R_2} = -2C_Q\frac{\Delta\nu_2}{V} \qquad (2)$

C_{R_1} may be separated into the lift and drag components ΔC_{L_1} and ΔC_{D_1} respectively, by the relation:

$$\Delta C_{L_1} = C_{R_1}\frac{\Delta\nu_1''}{\Delta\nu_1} = 2\ C_Q\frac{\Delta\nu_1''}{V}$$

and

$$\Delta C_{D_1} = C_{R_1}\frac{\Delta\nu_1'}{\Delta\nu_1} = 2\ C_Q\frac{\Delta\nu_1'}{V}$$

where $\Delta\nu_1''$ = component of $\Delta\nu_1$ in the lift direction,

and $\Delta\nu_1'$ = component of $\Delta\nu_1$ in the drag direction.

If the air taken in is undisturbed by the flow around the airfoil

$$\Delta\nu_1'' = O$$

and $\qquad \Delta\nu_1' = V$

and thus $\qquad C_{R_1} = \Delta C_{D_1}'$

but if the air is taken in through a slot in the surface of the airfoil, the value of the ratio $\frac{\Delta\nu_1}{V}$ may vary from a value greater than unity to a small negative value, depending upon the slot location and the character of the air flow, and in this case, C_{R_1} may have the lift component.

In equation (2), $\Delta\nu_2$ may be given any value depending upon the pressure maintained inside the airfoil. C_{R_2} may be separated into the lift and drag components ΔC_{L_2} and ΔC_{D_2} respectively, by the relation:

$$\Delta C_{D_2} = R_2 \cos(\alpha+\theta)$$

and $\qquad \Delta C_{L_2} = R_2 \sin(\alpha+\theta)$

where α = angle of attack, i. e., angle between some reference line on the airfoil and the direction of motion,

and θ = angle between the reference line on the airfoil and the axis of the jet.

Since in this investigation the slot opened nearly tangent to the upper surface of the airfoil, the jet tended to follow the surface, even when the airfoil had no motion, and hence the angle θ can only be approximated. Certain special cases will be taken up later, when θ and C_P will be given definite values.

Now consider the power required to maintain the pressure inside the airfoil which caused the air to flow through the opening in the airfoil. This power is conveniently represented by a coefficient C_{DS} which has been explained and derived under "Results," and is given by:

$$C_{DS}=C_P C_Q. \tag{3}$$

This relation is based on the condition that C_P is referred to the static pressure of the undisturbed air, and it includes only the pressure necessary to maintain the air flow through the slot. If this air is replenished from, or discharged into, the atmosphere at a velocity with respect to the airfoil, an additional pressure difference, represented by $\Delta\ C_P$, is required to accelerate the air up to this velocity. The additional power required to maintain $\Delta\ C_P$ may be represented, as above, by $\Delta\ C_{DS}$, which may be computed from the following relation:

$$\Delta\ C_{DS}=\Delta\ C_P C_Q \tag{4}$$

The manner in which the air was furnished to or conducted from the airfoil during the tests gave the same effect as though the air which flowed in or out through the slot was carried along inside the airfoil at a constant pressure. In the practical case, the air would have to flow into the airfoil through an opening and out through the slot or vice versa. If we now consider the above condition and separate all the forces and equivalent force coefficients into their respective parts, the resulting values of (C_D+C_{DS}) and C_L, which will be represented by C_D' and C_L' may be computed from the following relation:

$$C_D'=C_{D0}+2\ C_Q\frac{\Delta\nu_1'}{V}+2\ C_Q\frac{\Delta\nu_2}{V}\cos\ (\alpha+\theta)+C_{DS}+\Delta\ C_P C_Q \tag{5}$$

and

$$C_L'=C_{L0}+2\ C_Q\frac{\Delta\nu_1''}{V}+2\ C_Q\frac{\Delta\nu_2}{V}\sin\ (\alpha+\theta), \tag{6}$$

where C_{D0} and C_{L0} are the coefficients of the forces acting on the airfoil other than those due to the air which flows through the slot.

Equations (5) and (6) are general for the air flowing through the slot in either direction.

The above equations for air flow in through the slot reduce to:

$$C_D'=C_D+2C_Q\frac{\Delta\nu_2}{V}\cos(\alpha+\theta)+C_{DS}+\Delta C_P C_Q, \tag{7}$$

and $$C_L'=C_L+2C_Q\frac{\Delta\nu_2}{V}\sin(\alpha+\theta), \tag{8}$$

and for air flow out through the slot, they reduce to:

$$C_D'=C_D+2\ C_Q\frac{\Delta\nu_1'}{V}+C_{DS}+\Delta C_P C_Q, \tag{9}$$

and $$C_L'=C_L+2C_Q\frac{\Delta\nu_1''}{V}. \tag{10}$$

Improved flow will be considered as any change in the air flow around the airfoil which will result in an increase in C_L, or a decrease in C_D, or both. The action of the boundary layer in decreasing the lift and in increasing the profile drag, as compared with that which would be obtained with an inviscid fluid, has been explained in the introduction. However, a better understanding of the manner in which the air flowing through the slot improves the flow is essential to the interpretation of the results. Consider, first, that the air flows out of the slot as a jet. If this jet adds more energy to the boundary layer than is required to overcome the effect of viscosity, the air flowing over the upper surface of the airfoil will be given a higher velocity than would exist in an inviscid fluid. Since the flow of air around airfoils may be considered as a superimposed translation and circulation, and since the lift is proportional to the circulation, it might be expected that a lift greater than the theoretical could be obtained. Now consider the air flowing in through the slot. If the air of the boundary layer is removed as fast as it is formed, then the flow about the airfoil should give about the same lift as would be expected from an inviscid fluid. If more air is removed through the slot than is formed in the boundary layer, very small additional increases in lift, if any, could be expected, since the air flows from all directions to enter the slot; therefore there could be only a small resulting increase in velocity over the upper surface of the airfoil.

The profile drag of an airfoil is the result of skin friction, together with a resultant force due to the pressure distribution on the airfoil, caused by the change in flow of the air about the airfoil from that which would exist in an inviscid fluid. Since the effect of boundary layer control is to increase the velocity along the surface, the profile drag due to skin friction would be expected to increase. However, the resultant pressure due to the change in flow would be expected to reduce the profile drag. For these reasons, the profile drag could not be expected to be reduced appreciably for small values of the lift coefficient, even though the flow were considerably improved. No tests were made in this investigation to determine the individual effects mentioned above. However, it is believed that a fair approximation of the increase in lift and decrease in profile drag may be obtained by the proper assumptions and use of equations (5) and (6) mentioned above. In these equations, C_{D_0} and C_{L_0} are the coefficients which would be obtained by the improved flow, and the relation from which they may be computed is:

$$C_{D_0}=C_D-2C_Q\frac{\Delta\nu_1'}{V} \tag{11}$$

$$C_{L_0}=C_L-2C_Q\frac{\Delta\nu_1''}{V} \tag{12}$$

for the air flowing in through the slot, and

$$C_{D_0}=C_D-2C_Q\frac{\Delta\nu_2}{V}\cos(\alpha+\theta) \tag{13}$$

$$C_{L_0}=C_L-2C_Q\frac{\Delta\nu_2}{V}\sin(\alpha+\theta) \tag{14}$$

for the air flowing out through the slot.

To illustrate the above principles, as applied to the test data, the following examples are given. First consider changes in C_D, C_{DS}, and C_L, which may result from discharging or replenishing the air inside the airfoil to or from the outside atmosphere. By a suitable arrangement for discharging the air rearward from the airfoil into the atmosphere at a velocity equal to the velocity of motion, equations (7) and (8) reduce to:

$$\begin{aligned} C_D' &= (C_D-2C_Q)+(C_{DS}+C_Q) \\ &= C_D+C_{DS}-C_Q \end{aligned} \tag{15}$$

and $$C_L'=C_L \tag{16}$$

Since by the above arrangement.

$$\frac{\Delta\nu_2}{V}=\Delta C_p=1,$$

and $$\alpha+\theta=180°$$

Then: $$\cos(\alpha+\theta)=-1$$

and $$\sin(\alpha+\theta)=0$$

If θ has a constant value, the angle of attack (α) may be changed several degrees without introducing an appreciable error in the results obtained from equations (15) and (16).

Also by making

$$(\alpha+\theta)=90°$$

then $$C_D'=C_D+C_{DS}+C_Q$$

and $$C_L'=C_L+2C_Q.$$

However, from the standpoint of efficiency, it would be better to reduce C_D' than to obtain the comparatively small increase in C_L.

Now consider that an air intake for replenishing the air in the airfoil opens in the direction of motion. Then equations (9) and (10) will reduce to:

$$\begin{aligned} C_D' &= (C_D+2C_Q)+(C_{DS}-C_Q) \\ &= C_D+C_{DS}+C_Q \end{aligned} \tag{17}$$

and $$C_L'=C_L \tag{18}$$

since by the above arrangement

$$\Delta\nu_1'=V$$

$$\Delta\nu_1''=0$$

$$\Delta C_P=-1$$

These changes are important in the practical application of the data, and Figure 27 is given as an example to show the difference between the corrected and uncorrected data.

The changes in C_D due to the improved air flow about the airfoil could be computed by equations (11) and (13), if $\Delta\nu_1'$ in (11) and $(\alpha+\theta)$ in (13) were known. The factors $2C_Q\frac{\Delta\nu_1'}{V}$ and $2C_Q\frac{\Delta\nu_2}{V}\cos(\alpha+\theta)$ are both large when compared to C_D, and special tests would have to be made to determine these values.

The changes in C_L due to the improved flow may be computed from equations (12) and (14), since the values of $2C_Q\frac{\Delta\nu_1''}{V}$ and $2C_Q\frac{\Delta\nu_2}{V}\sin(\alpha+\theta)$ are both small as compared to C_L, even though $\frac{\Delta\nu_1''}{V}=1$ and sin

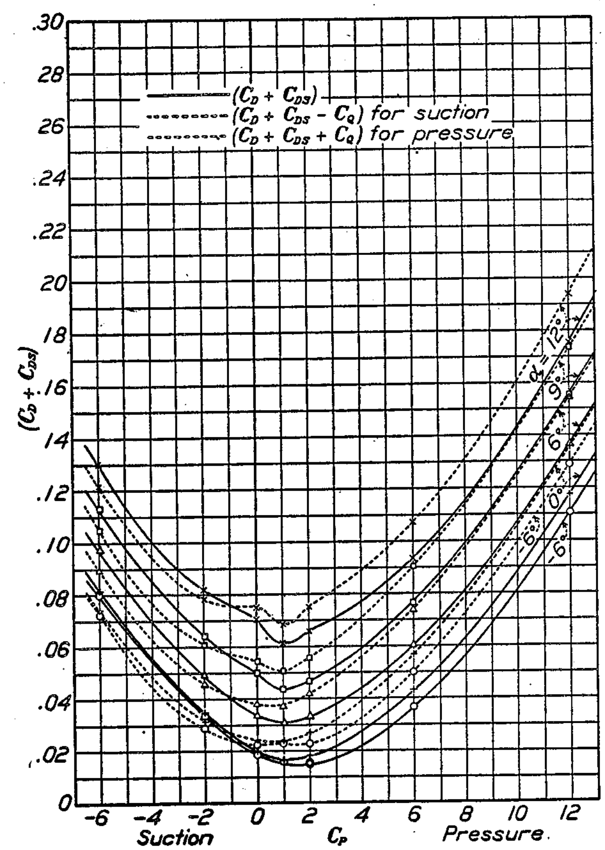

FIGURE 27.—Changes in drag due to method of supplying air to or exhausting it from interior of wing. Slot at 53.9 per cent chord from L. E., slot open 0.667 per cent chord

$(\alpha+\theta)=1$. Since, for values of C_Q and C_P of the same magnitude as those used in this investigation and at the small angles of attack, $\Delta\nu_1''$ and $\sin(\alpha+\theta)$ are both small, we may let $C_L=C_{L_0}$ without introducing an appreciable error in the results. Figure 28 shows that at small angles of attack there is very little increase in lift obtained by increasing the volume of air flowing in through the slot beyond a certain amount, while with the air flowing out through the slot the lift continues to increase with the volume. The values for the theoretical lift coefficients shown in

Figure 28 were determined by the relation given in Reference 17, the angle of zero lift being obtained from Munk's integrals. (Reference 18.)

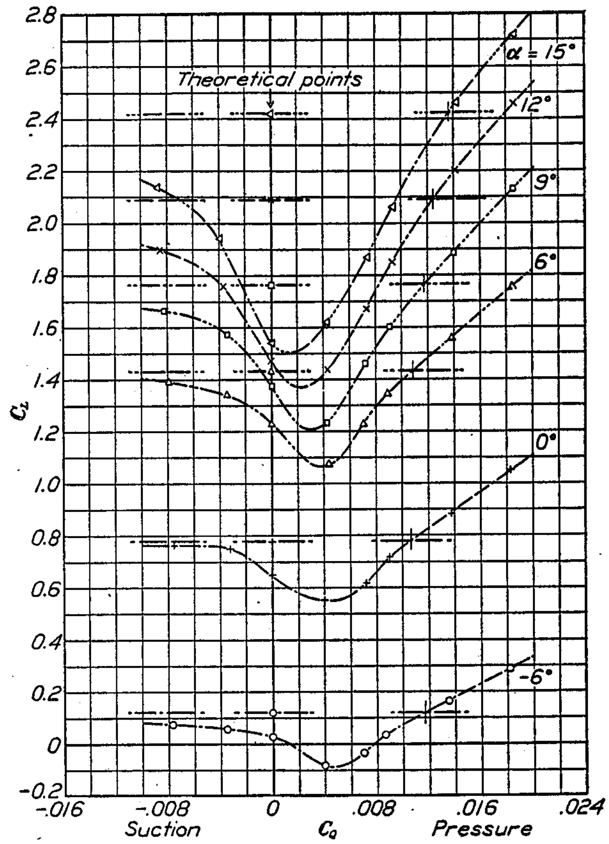

FIGURE 28.—Change in lift with change in slot air quantity. Slot at 53.9 per cent chord from L. E., slot open 0.667 per cent chord

SYMBOLS USED IN APPENDIX I

V = velocity of the airfoil through the air.

Δv_1 = change in the velocity of the air which is taken into the airfoil.

$\Delta v_1'$ = component of Δv_1 in the drag direction.

$\Delta v_1''$ = component of Δv_1 in the lift direction.

Δv_2 = jet velocity of the air flowing out of the airfoil.

R_1 = reaction produced by air flowing into the airfoil.

R_2 = reaction produced by air flowing out of the airfoil.

C_{R1} = R_1 reduced to coefficient form.

C_{R2} = R_2 reduced to coefficient form.

ΔC_{D1} = component of C_{R1} in the drag direction.

ΔC_{L1} = component of C_{R1} in the lift direction.

ΔC_{D2} = component of C_{R2} in the drag direction.

ΔC_{L2} = component of C_{R2} in the lift direction.

p = pressure difference maintained inside of the airfoil which induces the air velocity in or out through the slot.

ΔP = the additional pressure difference required to replenish from, or discharge into the atmosphere, at a velocity with respect to the airfoil, the air which flows in or out through the slot.

ΔC_P = ΔP reduced to coefficient form.

ΔC_{DS} = change in the coefficient C_{DS} produced by ΔC_P.

C_D' = total drag coefficient.

C_L' = total lift coefficient.

C_{D0} & C_{L0} = coefficients of the forces acting on the airfoil other than those due to the air which flows through the slot.

LANGLEY MEMORIAL AERONAUTICAL LABORATORY,
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
LANGLEY FIELD, VA., *November 26, 1930.*

TABLE II.—N. A. C. A. 84–M PROFILE; NO SLOTS; AVERAGE OF 5 TRIALS

α in degrees	−6	0	6	9	12	15	18	21	24	27	30
C_L	0.0340	0.6810	1.193	1.342	1.434	1.487	1.473	1.421	1.145	1.096	1.204
C_D	.0200	.0243	.0380	.0527	.0806	.1202	.1883	.2713	.4910	.5960	.7310

TABLE III.—N. A. C. A. 84–M PROFILE; SLOT 13.1 PER CENT OF CHORD FROM LEADING EDGE; SLOT OPEN 0.167 PER CENT CHORD

	α in degrees	−6	0	6	9	12	15	18	21	24	27	30
No flow through slot	C_L	0.0438	0.6860	1.097	1.270	1.390	1.480	1.475	1.385	1.102	1.125	1.238
	C_D	.0216	.0283	.0464	.0702	.0984	.1397	.2040	.2619	.5060	.6250	.7600
Suction =6 C_P	C_L	0.1060	0.7780	1.361	1.587	1.687	1.797	1.871	1.780	1.153	1.140	1.241
	C_D	.0313	.0359	.0522	.0684	.0862	.1153	.1571	.2298	.5130	.6280	.7770
	C_{DS}	.0273	.0258	.0242	.0238	.0219	.0211	.0215	.0219	.0265	.0253	.0253
	C_D+C_{DS}	.0586	.0617	.0764	.0922	.1081	.1364	.1786	.2517	.5395	.6533	.8023
	C_Q	.0046	.0043	.0041	.0040	.0037	.0035	.0036	.0037	.0044	.0042	.0042
Suction =2 C_P	C_L	0.0930	0.7490	1.245	1.377	1.484	1.546	1.541	1.527	1.112	1.130	1.250
	C_D	.0238	.0304	.0472	.0639	.0901	.1260	.1926	.2503	.5040	.6280	.7700
	C_{DS}	.0042	.0035	.0027	.0019	.0011	.0008	.0011	.0013	.0034	.0032	.0028
	C_D+C_{DS}	.0280	.0339	.0499	.0658	.0912	.1268	.1937	.2516	.5074	.6312	.7728
	C_Q	.0021	.0017	.0014	.0010	.0006	.0004	.0006	.0006	.0017	.0016	.0014
Static pressure	C_L	0.0470	0.6250	1.020	1.172	1.293	1.348	1.350	1.314	1.108	1.130	1.220
	C_D	.0196	.0280	.0520	.0827	.1137	.1532	.2060	.2630	.4920	.6120	.7500
	C_Q	.0005	.0011	.0015	.0015	.0015	.0015	.0015	.0014	.0013	.0013	.0014
Pressure =1 C_P	C_L	0.0130	0.5960	1.006	1.156	1.283	1.352	1.402	1.370	1.118	1.135	1.225
	C_D	.0187	.0260	.0502	.0802	.1095	.1432	.1947	.2510	.4870	.6120	.7420
	C_{DS}	.0015	.0020	.0022	.0023	.0022	.0023	.0023	.0022	.0020	.0020	.0020
	C_D+C_{DS}	.0202	.0280	.0524	.0825	.1117	.1455	.1970	.2532	.4890	.6140	.7440
	C_Q	.0015	.0020	.0023	.0023	.0022	.0023	.0023	.0023	.0021	.0020	.0021
Pressure =2 C_P	C_L	0	0.5760	1.013	1.160	1.299	1.380	1.443	1.440	1.122	1.135	1.230
	C_D	.0169	.0244	.0491	.0778	.1043	.1385	.1793	.2355	.4800	.6060	.7410
	C_{DS}	.0047	.0054	.0058	.0059	.0055	.0058	.0059	.0058	.0054	.0054	.0054
	C_D+C_{DS}	.0216	.0298	.0549	.0837	.1098	.1443	.1852	.2413	.4854	.6114	.7464
	C_Q	.0024	.0027	.0029	.0030	.0028	.0029	.0030	.0030	.0027	.0027	.0027
Pressure =6 C_P	C_L	0.0180	0.6320	1.132	1.332	1.510	1.632	1.698	1.739	1.204	1.140	1.235
	C_D	.0075	.0150	.0338	.0505	.0757	.1074	.1487	.1990	.4570	.5830	.7210
	C_{DS}	.0277	.0296	.0311	.0315	.0296	.0304	.0300	.0304	.0284	.0278	.0284
	C_D+C_{DS}	.0352	.0446	.0649	.0820	.1053	.1378	.1787	.2294	.4854	.6108	.7494
	C_Q	.0047	.0049	.0052	.0053	.0049	.0051	.0050	.0051	.0047	.0046	.0047
Pressure =12 C_P	C_L	0.0670	0.7280	1.283	1.520	1.749	1.918	2.040	2.095	1.396	1.177	1.250
	C_D	−.0077	.0007	.0194	.0346	.0553	.0732	.1056	.1571	.4320	.5570	.6960
	C_{DS}	.0877	.0914	.0936	.0944	.0890	.0905	.0905	.0913	.0859	.0837	.0837
	C_D+C_{DS}	.0800	.0921	.1130	.1290	.1443	.1637	.1961	.2484	.5179	.6407	.7797
	C_Q	.0073	.0076	.0078	.0078	.0074	.0075	.0075	.0076	.0072	.0070	.0070

TABLE IV.—N. A. C. A. 84–M PROFILE; SLOT 13.1 PER CENT OF CHORD FROM LEADING EDGE; SLOT OPEN 0.333 PER CENT CHORD

	α in degrees	−6	0	6	9	12	15	18	21	24	27	30
No flow through slot	C_L	0.0310	0.6690	1.088	1.257	1.392	1.463	1.468	1.384	1.110	1.128	1.240
	C_D	.0228	.0290	.0466	.0720	.0998	.1413	.1987	.2641	.5040	.6290	.7650
Suction =6 C_P	C_L	0.0619	0.7090	1.262	1.505	1.680	1.790	1.887	1.910	1.913	1.170	1.264
	C_D	.0322	.0356	.0485	.0607	.0785	.1087	.1390	.1850	.2370	.6170	.7650
	C_{DS}	.0333	.0295	.0273	.0258	.0276	.0269	.0279	.0325	.0298	.0437	.0415
	C_D+C_{DS}	.0655	.0651	.0758	.0865	.1061	.1356	.1669	.2175	.2668	.6607	.8065
	C_Q	.0056	.0049	.0046	.0043	.0046	.0045	.0046	.0054	.0050	.0073	.0069
Suction =2 C_P	C_L	0.0516	0.7090	1.231	1.375	1.472	1.513	1.547	1.523	Unstable	1.152	1.254
	C_D	.0265	.0296	.0427	.0583	.0871	.1283	.1778	.2280		.6150	.7620
	C_{DS}	.0052	.0039	.0029	.0023	.0013	0	0	0		.0056	.0052
	C_D+C_{DS}	.0317	.0335	.0456	.0606	.0884	.1283	.1778	.2280		.6206	.7672
	C_Q	.0026	.0020	.0015	.0011	.0007	0	0	0		.0028	.0026
Static pressure	C_L	0.0021	0.5930	1.014	1.160	1.260	1.310	1.360	1.360	1.354	1.145	1.232
	C_D	.0212	.0255	.0428	.0707	.1035	.1455	.1922	.2536	.3060	.5960	.7390
	C_Q	.0010	.0020	.0027	.0028	.0031	.0031	.0031	.0032	.0031	.0030	.0031
Pressure =1 C_P	C_L	0.0010	0.6030	1.030	1.200	1.332	1.428	1.516	1.550	1.571	1.142	1.248
	C_D	.0177	.0214	.0371	.0609	.0878	.1180	.1705	.2314	.2890	.5800	.7230
	C_{DS}	.0026	.0032	.0040	.0041	.0043	.0044	.0047	.0047	.0047	.0042	.0043
	C_D+C_{DS}	.0203	.0246	.0411	.0650	.0921	.1224	.1752	.2361	.2937	.5842	.7273
	C_Q	.0026	.0032	.0040	.0041	.0043	.0044	.0047	.0047	.0047	.0042	.0044
Pressure =2 C_P	C_L	0.0052	0.6220	1.100	1.282	1.460	1.596	1.677	1.720	1.753	1.160	1.232
	C_D	.0147	.0178	.0316	.0470	.0745	.1051	.1539	.2114	.2690	.5720	.7180
	C_{DS}	.0079	.0081	.0098	.0099	.0105	.0109	.0113	.0114	.0113	.0101	.0103
	C_D+C_{DS}	.0226	.0259	.0414	.0569	.0850	.1160	.1652	.2228	.2803	.5821	.7283
	C_Q	.0039	.0041	.0049	.0050	.0053	.0054	.0056	.0057	.0057	.0051	.0051
Pressure =6 C_P	C_L	0.0750	0.7420	1.325	1.572	1.818	2.030	2.150	2.230	Unstable	1.210	1.259
	C_D	−.0035	.0003	.0153	.0288	.0465	.0608	.0794	.1259		.5380	.6710
	C_{DS}	.0413	.0436	.0452	.0463	.0480	.0492	.0506	.0517		.0517	.0474
	C_D+C_{DS}	.0378	.0439	.0605	.0751	.0945	.1100	.1300	.1776		.5897	.7184
	C_Q	.0069	.0073	.0075	.0077	.0080	.0082	.0084	.0086		.0086	.0079
Pressure =12 C_P	C_L	0.1523	0.8350	1.450	1.728	2.023	2.290	2.460	2.623	Unstable	1.488	1.310
	C_D	−.0324	−.0274	−.0106	.0046	.0214	.0391	.0675	.0948		.5150	.6500
	C_{DS}	.1186	.1202	.1240	.1248	.1297	.1352	.1392	.1432		.1293	.1277
	C_D+C_{DS}	.0862	.0928	.1134	.1294	.1511	.1743	.2067	.2380		.6443	.7777
	C_Q	.0099	.0101	.0104	.0104	.0108	.0113	.0116	.0119		.0108	.0107

TABLE V.—N. A. C. A. 84–M PROFILES; SLOT 13.1 PER CENT OF CHORD FROM LEADING EDGE; SLOT OPEN 0.500 PER CENT CHORD

	α in degrees	−6	0	6	9	12	15	18	21	24	27	30
No flow through slot	C_L	0.0210	0.6270	1.082	1.260	1.390	1.484	1.523	1.442	1.152	1.152	1.264
	C_D	.0232	.0274	.0444	.0686	.0961	.1361	.1873	.2530	.5000	.6230	.8110
Suction =6 C_P	C_L	0.0675	0.7160	1.264	1.510	1.704	1.840	1.938	1.990	2.008	1.211	1.270
	C_D	.0348	.0379	.0505	.0629	.0825	.1060	.1455	.1893	.2380	.6190	.7690
	C_{DS}	.0395	.0355	.0336	.0313	.0330	.0318	.0334	.0342	.0360	.0538	.0507
	C_D+C_{DS}	.0743	.0734	.0841	.0942	.1155	.1378	.1789	.2235	.2740	.6728	.8197
	C_Q	.0066	.0059	.0056	.0052	.0055	.0053	.0056	.0057	.0060	.0090	.0085
Section =2 C_P	C_L	0.0649	0.7140	1.242	1.407	1.480	1.519	1.548	1.540	1.567	1.150	1.254
	C_D	.0278	.0306	.0434	.0581	.0886	.1297	.1808	.2280	.2850	.6190	.7690
	C_{DS}	.0063	.0047	.0033	.0029	.0017	.0018	0	.0009	.0032	.0081	.0074
	C_D+C_{DS}	.0341	.0353	.0467	.0610	.0903	.1315	.1808	.2289	.2882	.6271	.7764
	C_Q	.0031	.0024	.0017	.0015	.0008	.0009	0	.0005	.0016	.0040	.0037
Static Pressure	C_L	0	0.5820	0.9890	1.127	1.210	1.273	1.367	1.392	1.422	1.150	1.232
	C_D	.0226	.0244	.0443	.0725	.1072	.1442	.1960	.2550	.3160	.5910	.7320
	C_Q	.0003	.0028	.0039	.0041	.0042	.0044	.0046	.0046	.0046	.0043	.0044
Pressure =1 C_P	C_L	0.0078	0.5940	1.043	1.230	1.370	1.483	1.595	1.630	1.240	1.160	1.238
	C_D	.0156	.0181	.0384	.0551	.0814	.1102	.1720	.2270	.4400	.5670	.7070
	C_{DS}	.0040	.0049	.0056	.0058	.0060	.0062	.0064	.0066	.0062	.0060	.0060
	C_D+C_{DS}	.0196	.0230	.0440	.0609	.0874	.1164	.1784	.2336	.4462	.5730	.7130
	C_Q	.0040	.0049	.0056	.0058	.0060	.0062	.0064	.0066	.0062	.0060	.0060
Pressure =2 C_P	C_L	0.0310	0.6540	1.167	1.377	1.563	1.706	1.803	1.873	1.354	1.176	1.243
	C_D	.0092	.0118	.0247	.0369	.0570	.0862	.1357	.1870	.4250	.5550	.6950
	C_{DS}	.0112	.0128	.0140	.0144	.0151	.0155	.0160	.0164	.0147	.0147	.0145
	C_D+C_{DS}	.0204	.0246	.0387	.0513	.0721	.1017	.1517	.2034	.4397	.5697	.7095
	C_Q	.0056	.0064	.0070	.0072	.0076	.0077	.0080	.0082	.0073	.0073	.0073
Pressure =6 C_P	C_L	0.1300	0.8100	1.420	1.687	1.958	2.190	2.315	2.391	Unstable	1.379	1.285
	C_D	−.0205	−.0167	−.0008	.0136	.0301	.0447	.0715	.0998		.5160	.6580
	C_{DS}	.0598	.0625	.0644	.0664	.0674	.0693	.0704	.0712		.0669	.0654
	C_D+C_{DS}	.0393	.0458	.0636	.0800	.0975	.1140	.1419	.1710		.5829	.7234
	C_Q	.0100	.0104	.0107	.0111	.0112	.0116	.0117	.0119		.0112	.0109
Pressure =12 C_P	C_L	0.2280	0.9400	1.575	1.885	2.200	2.455	2.545	2.550	Unstable	1.595	1.383
	C_D	−.0660	−.0620	−.0434	−.0268	−.0123	.0090	.0425	.1258		.4750	.6380
	C_{DS}	.1657	.1702	.1727	.1756	.1780	.1795	.1826	.1857		.1780	.1740
	C_D+C_{DS}	.0997	.1082	.1293	.1488	.1657	.1885	.2251	.3115		.6530	.8120
	C_Q	.0138	.0142	.0144	.0147	.0148	.0150	.0152	.0155		.0148	.0146

TABLE VI.—N. A. C. A. 84–M PROFILE; SLOT 13.1 PER CENT OF CHORD FROM LEADING EDGE; SLOT OPEN 0.667 PER CENT CHORD

	α in degrees	−6	0	6	9	12	15	18	21	24	27	30
No flow through slot	C_L	0	0.6110	1.080	1.256	1.392	1.474	1.529	1.450	1.165	1.140	1.256
	C_D	.0239	.0282	.0448	.0691	.0973	.1373	.1855	.2520	.5040	.6200	.7600
Suction =6 C_P	C_L	0.0657	0.7080	1.265	1.504	1.690	1.860	1.960	2.030	2.070	1.248	1.260
	C_D	.0373	.0399	.0521	.0650	.0829	.1029	.1410	.1833	.2330	.6170	.7610
	C_{DS}	.0463	.0414	.0373	.0358	.0377	.0368	.0386	.0407	.0428	.0689	.0637
	C_D+C_{DS}	.0836	.0813	.0894	.1008	.1206	.1397	.1796	.2240	.2758	.6859	.8247
	C_Q	.0077	.0069	.0062	.0060	.0063	.0061	.0064	.0068	.0071	.0115	.0106
Suction =2 C_P	C_L	0.0579	0.7080	1.250	1.415	1.485	1.505	1.554	1.556	1.585	1.143	1.250
	C_D	.0295	.0321	.0435	.0577	.0875	.1264	.1750	.2230	.2790	.6140	.7590
	C_{DS}	.0079	.0060	.0041	.0034	.0029	0	0	.0018	.0033	.0167	.0093
	C_D+C_{DS}	.0374	.0381	.0476	.0611	.0904	.1264	.1750	.2248	.2823	.6307	.7683
	C_Q	.0039	.0030	.0021	.0017	.0014	0	0	.0009	.0017	.0053	.0046
Static pressure	C_L	−0.0090	0.5560	0.9490	1.078	1.160	1.226	1.305	1.370	1.430	1.135	1.240
	C_D	.0232	.0238	.0444	.0755	.1125	.1470	.1972	.2520	.3050	.5700	.7220
	C_Q	.0028	.0034	.0048	.0049	.0052	.0055	.0057	.0058	.0061	.0057	.0058
Pressure= 1 C_P	C_L	0.0013	0.5900	1.040	1.230	1.386	1.510	1.640	1.677	1.661	1.175	1.220
	C_D	.0132	.0151	.0296	.0481	.0746	.1039	.1563	.2080	.2730	.5490	.6810
	C_{DS}	.0049	.0061	.0071	.0073	.0077	.0081	.0084	.0086	.0087	.0079	.0080
	C_D+C_{DS}	.0181	.0212	.0367	.0554	.0823	.1120	.1647	.2166	.2817	.5569	.6890
	C_Q	.0049	.0061	.0071	.0073	.0077	.0081	.0084	.0086	.0087	.0079	.0080
Pressure= 2 C_P	C_L	0.0370	0.6770	1.205	1.425	1.610	1.790	1.870	1.942	1.904	1.192	1.222
	C_D	.0036	.0054	.0179	.0298	.0460	.0694	.1196	.1628	.2440	.5330	.6790
	C_{DS}	.0157	.0161	.0178	.0183	.0190	.0202	.0208	.0214	.0211	.0193	.0191
	C_D+C_{DS}	.0193	.0215	.0357	.0481	.0650	.0896	.1404	.1842	.2651	.5523	.6981
	C_Q	.0078	.0081	.0089	.0091	.0095	.0102	.0104	.0107	.0106	.0097	.0095
Pressure= 6 C_P	C_L	0.1510	0.8400	1.452	1.735	2.021	2.260	2.405	2.544		1.485	1.290
	C_D	−.0380	−.0339	−.0183	−.0033	.0103	.0256	.0539	.0706		.4790	.6360
	C_{DS}	.0747	.0776	.0814	.0817	.0837	.0878	.0902	.0916	Unstable	.0871	.0840
	C_D+C_{DS}	.0367	.0437	.0631	.0784	.0940	.1134	.1441	.1622		.5661	.7200
	C_Q	.0124	.0129	.0136	.0136	.0139	.0177	.0150	.0153		.0145	.0140
Pressure= 12 C_P	C_L	0.2650	0.9830	1.630	1.965	2.280	2.561	2.730	2.422		1.770	1.570
	C_D	−.1010	−.0964	−.0801	−.0650	----------	−.0319	−.0071	.1000		.4250	.6030
	C_{DS}	.2053	.2090	.2136	.2167	.2174	.2273	.2305	.2378	Unstable	.2282	.2230
	C_D+C_{DS}	.1043	.1126	.1335	.1517	----------	.1954	.2234	.3378		.6530	.8260
	C_Q	.0171	.0174	.0178	.0181	.0181	.0190	.0192	.0198		.0191	.0186

TABLE VII.—N. A. C. A. 84–M PROFILE; SLOT 32.55 PER CENT OF CHORD FROM LEADING EDGE; SLOT OPEN 0.167 PER CENT CHORD

	α in degrees	−6	0	6	9	12	15	18	21	24	27	30
No flow through slot	C_L	0.0230	0.6780	1.190	1.380	1.458	1.520	1.540	1.480	1.180	1.142	1.243
	C_D	.0210	.0254	.0390	.0540	.0850	.1220	.1630	.2680	.4620	.6050	.7400
Suction $=6\ C_P$	C_L	0.0415	0.7100	1.310	1.490	1.620	1.730	1.758	Unstable	1.174	1.139	1.248
	C_D	.0252	.0280	.0408	.0548	.0724	.1048	.1483		.5150	.6250	.7570
	C_{DS}	.0139	.0135	.0131	.0126	.0124	.0126	.0132		.0141	.0139	.0141
	C_D+C_{DS}	.0391	.0415	.0539	.0674	.0848	.1174	.1615		.5291	.6389	.7711
	C_Q	.0023	.0023	.0022	.0021	.0021	.0021	.0022		.0024	.0023	.0024
Suction $=2\ C_P$	C_L	0.0311	0.6940	1.223	1.440	1.540	1.633	1.610	1.506	1.174	1.160	1.248
	C_D	.0231	.0265	.0396	.0527	.0817	.1075	.1818	.2870	.5200	.6230	.7640
	C_{DS}	.0022	.0018	.0014	.0014	.0013	.0015	.0018	.0020	.0019	.0018	.0016
	C_D+C_{DS}	.0253	.0283	.0410	.0541	.0830	.1090	.1836	.2890	.5219	.6248	.7656
	C_Q	.0011	.0009	.0007	.0007	.0006	.0008	.0009	.0010	.0010	.0009	.0008
Static Pressure	C_L	0	0.6430	1.183	1.352	1.405	1.452	1.535	1.485	1.180	1.150	1.237
	C_D	.0345	.0250	.0393	.0563	.0937	.1300	.1860	.2635	.5000	.6170	.7470
	C_Q	.0005	.0006	.0008	.0008	.0008	.0006	.0006	.0006	.0008	.0008	.0008
Pressure $=1\ C_P$	C_L	−0.0080	0.6370	1.160	1.352	1.413	1.483	1.545	1.518	1.163	1.150	1.258
	C_D	.0216	.0244	.0383	.0530	.0883	.1218	.1580	.2645	.5000	.6130	.7480
	C_{DS}	.0011	.0011	.0013	.0013	.0012	.0011	.0011	.0011	.0011	.0011	.0012
	C_D+C_{DS}	.0227	.0255	.0396	.0543	.0895	.1229	.1591	.2656	.5011	.6141	.7492
	C_Q	.0011	.0011	.0013	.0013	.0012	.0011	.0011	.0011	.0011	.0011	.0012
Pressure $=2\ C_P$	C_L	−0.008	0.6350	1.165	1.361	1.445	1.535	1.570	1.508	1.153	1.139	1.258
	C_D	.0203	.0231	.0370	.0510	.0797	.1096	.1487	.2645	.5000	.6060	.7520
	C_{DS}	.0029	.0030	.0033	.0033	.0033	.0032	.0032	.0030	.0031	.0030	.0032
	C_D+C_{DS}	.0232	.0261	.0403	.0543	.0830	.1128	.1519	.2675	.5031	.6090	.7552
	C_Q	.0015	.0015	.0016	.0016	.0016	.0016	.0016	.0015	.0015	.0015	.0016
Pressure $=6\ C_P$	C_L	0.0181	0.6820	1.250	1.470	1.605	1.728	1.830	1.620	1.158	1.143	1.258
	C_D	.0166	.0194	.0323	.0456	.0662	.0954	.1422	.2360	.4940	.6050	.7490
	C_{DS}	.0160	.0162	.0165	.0165	.0167	.0167	.0165	.0164	.0162	.0161	.0161
	C_D+C_{DS}	.0326	.0356	.0488	.0621	.0829	.1121	.1587	.2524	.5102	.6211	.7651
	C_Q	.0027	.0027	.0028	.0028	.0028	.0028	.0028	.0027	.0027	.0027	.0027
Pressure $=12\ C_P$	C_L	0.0570	0.7350	1.342	1.610	1.800	1.950	2.045	1.767	1.148	1.170	1.258
	C_D	.0086	.0119	.0266	.0415	.0602	.0787	.1205	.2345	.4900	.5970	.7430
	C_{DS}	.0473	.0482	.0489	.0494	.0497	.0497	.0497	.0490	.0478	.0478	.0482
	C_D+C_{DS}	.0559	.0601	.0755	.0909	.1099	.1284	.1702	.2835	.5378	.6448	.7912
	C_Q	.0040	.0040	.0041	.0041	.0042	.0042	.0042	.0041	.0040	.0040	.0040

TABLE VIII.—N. A. C. A. 84–M PROFILE; SLOT 32.55 PER CENT OF CHORD FROM LEADING EDGE; SLOT OPEN 0.333 PER CENT CHORD

	α in degrees	−6	0	6	9	12	15	18	21	24	27	30
No flow through slot	C_L	0.0080	0.6550	1.193	1.378	1.454	1.530	1.539	1.472	1.174	1.137	1.250
	C_D	.0220	.0251	.0388	.0542	.0824	.1175	.1629	.2650	.4640	.6030	.7360
Suction =6 C_P	C_L	0.0470	0.7180	1.310	1.548	1.711	1.902	2.020	2.050	1.190	1.143	1.263
	C_D	.0304	.0327	.0457	.0582	.0745	.0968	.1313	.1772	.4910	.6060	.7350
	C_{DS}	.0307	.0292	.0280	.0280	.0280	.0286	.0296	.0323	.0375	.0374	.0366
	C_D+C_{DS}	.0611	.0619	.0737	.0862	.1025	.1254	.1609	.2095	.5285	.6434	.7716
	C_Q	.0051	.0049	.0047	.0047	.0047	.0048	.0049	.0054	.0063	.0062	.0061
Suction =2 C_P	C_L	0.0410	0.7030	1.295	1.465	1.588	1.728	1.787	Unstable	1.180	1.149	1.242
	C_D	.0250	.0273	.0394	.0529	.0713	.1056	.1501		.4870	.5960	.7290
	C_{SD}	.0044	.0037	.0032	.0028	.0028	.0028	.0033		.0049	.0048	.0045
	C_D+C_{DS}	.0294	.0310	.0426	.0557	.0741	.1084	.1534		.4919	.6008	.7335
	C_Q	.0022	.0019	.0016	.0014	.0014	.0014	.0017		.0025	.0024	.0023
Static pressure	C_L	−0.0210	0.5950	1.096	1.294	1.339	1.418	1.519	1.541	1.170	1.149	1.242
	C_D	.0211	.0234	.0371	.0560	.0939	.1247	.1554	.2480	.4760	.5830	.7150
	C_Q	.0015	.0021	.0025	.0024	.0023	.0022	.0022	.0021	.0023	.0024	.0025
Pressure =1 C_P	C_L	−0.0210	0.6000	1.124	1.330	1.440	1.563	1.704	1.681	1.165	1.149	1.252
	C_D	.0183	.0204	.0324	.0476	.0739	.1011	.1348	.2333	.4630	.5780	.7080
	C_{DS}	.0029	.0033	.0036	.0036	.0036	.0036	.0036	.0035	.0035	.0035	.0037
	C_D+C_{DS}	.0212	.0237	.0360	.0512	.0775	.1047	.1384	.2368	.4665	.5815	.7117
	C_Q	.0029	.0033	.0036	.0036	.0036	.0036	.0036	.0035	.0035	.0036	.0037
Pressure =2 C_P	C_L	0	0.6410	1.187	1.419	1.547	1.712	1.855	1.775	1.160	1.160	1.248
	C_D	.0139	.0162	.0287	.0417	.0594	.0827	.1153	.2040	.4500	.5760	.7030
	C_{DS}	.0080	.0082	.0088	.0088	.0089	.0090	.0091	.0089	.0086	.0086	.0088
	C_D+C_{DS}	.0219	.0244	.0375	.0505	.0683	.0917	.1244	.2129	.4586	.5846	.7118
	C_Q	.0040	.0041	.0044	.0044	.0045	.0045	.0046	.0045	.0043	.0043	.0044
Pressure =6 C_P	C_L	0.0830	0.7700	1.390	1.658	1.890	2.120	2.280	2.370	1.190	1.185	1.252
	C_D	−.0019	.0012	.0158	.0303	.0477	.0611	.0842	.1184	.4720	.5760	.6980
	C_{DS}	.0388	.0396	.0407	.0412	.0412	.0420	.0422	.0424	.0401	.0401	.0398
	C_D+C_{DS}	.0369	.0408	.0565	.0715	.0889	.1031	.1264	.1608	.5121	.6161	.7378
	C_Q	.0065	.0066	.0068	.0069	.0069	.0070	.0070	.0071	.0067	.0067	.0066
Pressure =12 C_P	C_L	0.1550	0.8660	1.508	1.802	2.118	2.380	2.440	2.495	1.268	1.232	1.289
	C_D	−.0272	−.0223	−.0060	.0105	.0265	.0442	.0943	.1459	.4850	.5850	.6930
	C_{DS}	.1079	.1095	.1110	.1113	.1120	.1136	.1142	.1146	.1102	.1100	.1100
	C_D+C_{DS}	.0807	.0872	.1050	.1218	.1385	.1578	.2085	.2605	.5952	.6950	.8030
	C_Q	.0090	.0091	.0093	.0093	.0093	.0095	.0095	.0096	.0092	.0092	.0092

TABLE IX.—N. A. C. A. 84-M PROFILE; SLOT 32.55 PER CENT OF CHORD FROM LEADING EDGE; SLOT OPEN 0.500 PER CENT CHORD

	α in degrees	−6	0	6	9	12	15	18	21	24	27	30
No flow through slot	C_L C_D	0.0181 .0224	0.6620 .0260	1.205 .0400	1.380 .0557	1.465 .0843	1.538 .1196	1.540 .1670	1.471 .2860	1.160 .5070	1.123 .6210	1.233 .7490
Suction $=6\ C_P$	C_L C_D C_{DS} C_D+C_{DS} C_Q	0.0670 .0330 .0388 .0718 .0065	0.7300 .0357 .0374 .0731 .0062	1.345 .0497 .0358 .0855 .0060	1.575 .0642 .0374 .1016 .0062	1.780 .0815 .0371 .1186 .0062	1.990 .0980 .0378 .1358 .0063	2.130 .1242 .0396 .1638 .0066	2.200 .1670 .0433 .2103 .0072	1.160 .5200 .0560 .5760 .0093	1.160 .6500 .0543 .7043 .0091	1.276 .7820 .0541 .8361 .0090
Suction $=2\ C_P$	C_L C_D C_{DS} C_D+C_{DS} C_Q	0.0570 .0263 .0057 .0320 .0028	0.7300 .0288 .0049 .0337 .0025	1.319 .0420 .0044 .0464 .0022	1.520 .0558 .0043 .0601 .0022	1.632 .0741 .0039 .0780 .0019	1.790 .1076 .0039 .1115 .0020	1.870 .1448 .0046 .1494 .0023	Unstable	1.132 .5200 .0087 .5287 .0043	1.150 .6350 .0082 .6432 .0041	1.270 .7820 .0078 .7898 .0039
Static Pressure	C_L C_D C_Q	−0.0260 .0205 .0027	0.5570 .0225 .0036	1.105 .0371 .0042	1.265 .0612 .0041	1.318 .0923 .0039	1.452 .1220 .0039	1.580 .1542 .0039	1.550 .2125 .0039	1.120 .4940 .0040	1.150 .6040 .0042	1.260 .7470 .0043
Pressure $=1\ C_P$	C_L C_D C_{DS} C_D+C_{DS} C_Q	0.0130 .0135 .0050 .0185 .0050	0.6020 .0161 .0056 .0217 .0056	1.164 .0291 .0060 .0351 .0060	1.380 .0424 .0059 .0483 .0059	1.512 .0674 .0058 .0732 .0058	1.674 .0893 .0058 .0951 .0058	1.820 .1192 .0059 .1251 .0059	1.877 .1687 .0058 .1745 .0058	1.125 .4940 .0055 .4995 .0055	1.150 .5980 .0057 .6037 .0057	1.250 .7300 .0059 .7359 .0059
Pressure $=2\ C_P$	C_L C_D C_{DS} C_D+C_{DS} C_Q	0.0390 .0062 .0130 .0192 .0065	0.6870 .0088 .0139 .0227 .0070	1.278 .0223 .0146 .0369 .0073	1.530 .0347 .0146 .0493 .0073	1.706 .0530 .0144 .0674 .0072	1.872 .0735 .0145 .0880 .0073	2.015 .1033 .0147 .1180 .0074	2.090 .1428 .0148 .1576 .0074	1.148 .4840 .0128 .4968 .0064	1.164 .5980 .0142 .6122 .0071	1.260 .7300 .0142 .7442 .0071
Pressure $=6\ C_P$	C_L C_D C_{DS} C_D+C_{DS} C_Q	0.1630 −.0249 .0633 .0384 .0106	0.8500 −.0195 .0653 .0458 .0109	1.5101 −.0035 .0657 .0622 .0110	1.805 .0124 .0663 .0787 .0111	2.100 .0268 .0647 .0915 .0108	2.340 .0447 .0658 .1105 .0110	2.390 .0925 .0662 .1587 .0110	2.450 .1377 .0670 .2047 .0112	1.234 .4840 .0638 .5478 .0107	1.205 .5950 .0636 .6586 .0106	1.280 .7260 .0640 .7900 .0107
Pressure $=12\ C_P$	C_L C_D C_{DS} C_D+C_{DS} C_Q	0.2540 −.0693 .1710 .1017 .0142	0.9800 −.0651 .1740 .1089 .0145	1.670 −.0469 .1749 .1280 .0146	2.021 −.0312 .1757 .1445 .0146	2.330 −.0152 .1702 .1550 .0142	2.580 .0160 .1719 .1879 .0143	Unstable	2.710 .1010 .1719 .2729 .0143	1.585 .4620 .1700 .6320 .0142	1.304 .6020 .1692 .7712 .0141	1.374 .7260 .1700 .8960 .0142

TABLE X.—N. A. C. A. 84–M PROFILE; SLOT 32.55 PER CENT OF CHORD FROM LEADING EDGE; SLOT OPEN 0.667 PER CENT CHORD

	α in degrees	−6	0	6	9	12	15	18	21	24	27	30
No flow through slot	C_L	0.0180	0.6580	1.203	1.380	1.471	1.533	1.533	1.467	1.149	1.142	1.264
	C_D	.0230	.0262	.0398	.0544	.0831	.1203	.1660	.2910	.4970	.6070	.7610
Suction =6 C_P	C_L	0.0850	0.7490	1.330	1.603	1.780	2.010	2.165	2.245	1.206	1.168	1.297
	C_D	.0349	.0381	.0515	.0662	.0831	.1004	.1237	.1658	.5360	.6410	.7900
	C_{DS}	.0446	.0425	.0402	.0427	.0446	.0465	.0487	.0525	.0694	.0660	.0660
	$C_D + C_{DS}$	.0795	.0806	.0917	.1089	.1277	.1469	.1724	.2183	.6054	.7070	.8560
	C_Q	.0074	.0071	.0067	.0071	.0074	.0078	.0081	.0088	.0116	.0110	.0110
Suction =2 C_P	C_L	0.0750	0.7440	1.330	1.492	1.647	1.819	1.910	1.744	1.160	1.141	1.266
	C_D	.0264	.0295	.0422	.0550	.0731	.1010	.1400	.2900	.5100	.6270	.7640
	C_{DS}	.0067	.0055	.0047	.0046	.0046	.0048	.0058	.0087	.0114	.0110	.0100
	$C_D + C_{DS}$	.0331	.0350	.0469	.0596	.0777	.1058	.1458	.2987	.5214	.6380	.7740
	C_Q	.0033	.0028	.0024	.0024	.0023	.0024	.0029	.0043	.0057	.0053	.0049
Static Pressure	C_L	−0.0310	0.5220	1.077	1.209	1.290	1.441	1.565	1.585	1.135	1.141	1.235
	C_D	.0191	.0220	.0365	.0609	.0923	.1183	.1482	.2403	.4790	.6060	.7280
	C_Q	.0033	.0045	.0052	.0049	.0049	.0050	.0049	.0050	.0053	.0054	.0057
Pressure =1 C_P	C_L	−0.0050	0.6050	1.164	1.389	1.532	1.709	1.858	1.940	1.140	1.157	1.245
	C_D	.0103	.0127	.0251	.0377	.0583	.0792	.1164	.1576	.4890	.5900	.7180
	C_{DS}	.0062	.0069	.0074	.0074	.0076	.0078	.0079	.0080	.0075	.0076	.0077
	$C_D + C_{DS}$	.0165	.0196	.0325	.0451	.0659	.0870	.1243	.1656	.4965	.5976	.7257
	C_Q	.0062	.0069	.0074	.0074	.0076	.0078	.0079	.0080	.0075	.0076	.0077
Pressure =2 C_P	C_L	0.0540	0.7130	1.299	1.555	1.744	1.938	2.080	2.165	1.176	1.168	1.240
	D_D	.0005	.0034	.0167	.0284	.0442	.0631	.0906	.1218	.4820	.5860	.7180
	C_{DS}	.0160	.0173	.0181	.0184	.0187	.0191	.0195	.0196	.0183	.0184	.0190
	$C_D + C_{DS}$	.0165	.0207	.0348	.0468	.0629	.0822	.1101	.1414	.5003	.6044	.7370
	C_Q	.0080	.0087	.0091	.0092	.0093	.0096	.0097	.0098	.0092	.0092	.0094
Pressure =6 C_P	C_L	0.1860	0.8940	1.521	1.845	2.140	2.400	----------	2.495	1.382	1.240	1.302
	C_D	−.0398	−.0354	−.0186	−.0050	.0103	.0300	.1080	.1314	.4670	.5910	.7070
	C_{DS}	.0778	.0800	.0808	.0820	.0843	.0852	.0857	.0893	.0872	.0820	.082
	$C_D + C_{DS}$	.0380	.0446	.0622	.0770	.0946	.1152	.1937	.2207	.5542	.6730	.7890
	C_Q	.0130	.0133	.0135	.0137	.0140	.0142	.0143	.0149	.0146	.0137	.0137
Pressure =12 C_P	C_L	0.3050	1.052	1.753	2.095	2.400	2.560	2.850	1.950	1.693	1.364	1.416
	C_D	−.1014	−.0960	−.0790	−.0623	−.0456	.0150	----------	.2955	.4350	.5910	.7070
	C_{DS}	.2099	.2120	.2142	.2150	.2182	.2205	.2230	.2202	.2170	.2160	.2160
	$C_D + C_{DS}$	.1085	.1160	.1352	.1527	.1726	.2355	----------	.5157	.6520	.8070	.9230
	C_Q	.0175	.0177	.0179	.0179	.0182	.0184	.0186	.0184	.0182	.0180	.0180

TABLE XI.—N. A. C. A. 84–M PROFILE; SLOT 53.9 PER CENT OF CHORD FROM LEADING EDGE; SLOT OPEN 0.167 PER CENT CHORD

	α in degrees	−6	0	6	9	12	15	18	21	24	27	30
No flow through slot	C_L	0.0340	0.6850	1.219	1.375	1.470	1.535	1.515	1.487	1.179	1.138	1.242
	C_D	.0212	.0247	.0380	.0532	.0790	.1244	.1940	.2710	.4850	.6120	.741
Suction $=6\ C_P$	C_L	0.0700	0.7380	1.310	1.510	1.628	1.640	1.548	1.510	Unstable	1.134	1.238
	C_D	.0228	.0260	.0407	.0537	.0700	.1182	.1958	.2780		.6100	.7570
	C_{DS}	.0126	.0126	.0119	.0117	.0118	.0124	.0126	.0126		.0122	.0118
	C_D+C_{DS}	.0354	.0386	.0526	.0654	.0818	.1306	.2084	.2906		.6222	.7688
	C_Q	.0021	.0021	.0020	.0019	.0020	.0021	.0021	.0021		.0020	.0020
Suction $=2\ C_P$	C_L	0.0570	0.7050	1.264	1.447	1.562	1.583	1.535	1.472	Unstable	1.130	1.238
	C_D	.0218	.0249	.0385	.0515	.0730	.1256	.1905	.2720		.6060	.7570
	C_{DS}	.0019	.0017	.0016	.0017	.0017	.0018	.0018	.0018		.0017	.0015
	C_D+C_{DS}	.0237	.0266	.0401	.0532	.0747	.1274	.1923	.2738		.6077	.7585
	C_Q	.0010	.0008	.0008	.0008	.0008	.0009	.0009	.0009		.0008	.0008
Static Pressure	C_L	0.0182	0.6750	1.193	1.340	1.448	1.540	1.540	1.488	Unstable	1.124	1.253
	C_D	.0216	.0249	.0380	.0553	.0818	.1162	.1878	.2660		.6020	.7520
	C_Q	.0005	.0005	.0005	.0005	.0005	.0003	.0005	.0005		.0006	.0008
Pressure $=1\ C_P$	C_L	0.0129	0.6580	1.193	1.345	1.470	1.580	1.558	1.500	1.173	1.130	1.253
	C_D	.0201	.0234	.0376	.0530	.0766	.1028	.1846	.2710	.4970	.6000	.7450
	C_{DS}	.0009	.0010	.0010	.0009	.0009	.0009	.0009	.0009	.0010	.0010	.0011
	C_D+C_{DS}	.0210	.0244	.0386	.0539	.0775	.1037	.1855	.2719	.4980	.6010	.7461
	C_Q	.0009	.0010	.0010	.0009	.0009	.0009	.0009	.0009	.0010	.0010	.0011
Pressure $=2\ C_P$	C_L	0.0104	0.6530	1.201	1.365	1.502	1.628	1.572	1.510	1.163	1.124	1.228
	C_D	.0196	.0223	.0360	.0511	.0720	.0992	.1760	.2710	.4830	.5950	.7380
	C_{DS}	.0026	.0028	.0028	.0027	.0027	.0027	.0026	.0026	.0029	.0029	.0029
	C_D+C_{DS}	.0222	.0251	.0388	.0538	.0747	.1019	.1786	.2736	.4859	.5979	.7409
	C_Q	.0013	.0014	.0014	.0014	.0014	.0013	.0013	.0013	.0014	.0014	.0019
Pressure $=6\ C_P$	C_L	0.0337	0.6900	1.270	1.480	1.660	1.815	1.655	1.550	1.173	1.124	1.228
	C_D	.0157	.0186	.0330	.0469	.0632	.0870	.1610	.2690	.4780	.6000	.7430
	C_{DS}	.0145	.0145	.0147	.0145	.0147	.0145	.0143	.0143	.0143	.0145	.0145
	C_D+C_{DS}	.0302	.0331	.0477	.0614	.0779	.1015	.1753	.2833	.4923	.6145	.7575
	C_Q	.0024	.0024	.0025	.0024	.0025	.0024	.0024	.0024	.0024	.0024	.0024
Pressure $=12\ C_P$	C_L	0.0726	0.7450	1.350	1.596	1.821	1.990	1.775	1.580	1.173	1.140	1.238
	C_D	.0097	.0126	.0282	.0433	.0623	.0813	.1620	.2590	.4900	.6050	.7360
	C_{DS}	.0434	.0434	.0430	.0434	.0430	.4037	.0429	.0417	.0422	.0422	.0422
	C_D+C_{DS}	.0531	.0560	.0712	.0867	.1053	.1250	.2049	.3007	.5322	.6472	.7782
	C_Q	.0036	.0036	.0036	.0036	.0036	.0036	.0036	.0035	.0035	.0035	.0035

TABLE XII.—N. A. C. A. 84–M PROFILE; SLOT 53.9 PER CENT OF CHORD FROM LEADING EDGE; SLOT OPEN 0.333 PER CENT CHORD

	α in degrees	−6	0	6	9	12	15	18	21	24	27	30
No flow through slot	C_L	0.026	0.678	1.212	1.364	1.464	1.53	1.51	1.46	1.17	1.12	1.227
	C_D	.0216	.0241	.0383	.053	.077	.1258	.1932	.271	.492	.614	.750
Suction $=6C_P$	C_L	0.085	0.756	1.350	1.595	1.795	1.990	1.640	1.542	Unstable	1.142	1.258
	C_D	.0288	.0319	.0461	.0600	.0777	.0933	.2060	.2825		.6120	.755
	C_{DS}	.0300	.0296	.0298	.0304	.0314	.0322	.0372	.0379		.0371	.0368
	C_D+C_{DS}	.0588	.0615	.0759	.0904	.1091	.1255	.2432	.3204		.6491	.7918
	C_Q	.0050	.0049	.0050	.0051	.0052	.0054	.0062	.0063		.0062	.0061
Suction $=2C_P$	C_L	0.0725	0.7420	1.305	1.515	1.662	1.805	1.575	1.500	Unstable	1.128	1.244
	C_D	.0233	.0253	.0405	.0540	.0719	.0992	.1984	.2790		.6130	.7580
	C_{DS}	.0045	.0044	.0038	.0038	.0040	.0046	.0057	.0057		.0049	.0047
	C_D+C_{DS}	.0278	.0297	.0443	.0578	.0759	.1038	.2041	.2847		.6179	.7627
	C_Q	.0023	.0022	.0019	.0019	.0020	.0023	.0029	.0029		.0025	.0023
Static pressure	C_L	−0.0013	0.6120	1.153	1.295	1.425	1.587	1.570	1.500	1.168	1.133	1.238
	C_D	.0195	.0226	.0363	.5600	.7680	.0992	.1763	.2780	.490	.5980	.740
	C_Q	.0017	.0021	.0020	.0019	.0021	.0017	.0018	.0020	.0024	.0024	.0026
Pressure $=1C_P$	C_L	−0.0080	0.6270	1.192	1.378	1.559	1.735	1.630	1.533	1.168	1.136	1.248
	C_D	.0161	.0187	.0317	.0460	.0623	.0810	.1650	.2660	.490	.5980	.7250
	C_{DS}	.0031	.0033	.0033	.0033	.0033	.0033	.0032	.0033	.0036	.0036	.0037
	C_D+C_{DS}	.0192	.0220	.0350	.0493	.0656	.0843	.1682	.2693	.4936	.6016	.7287
	C_Q	.0031	.0034	.0033	.0033	.0033	.0033	.0032	.0033	.0036	.0036	.0037
Pressure $=2C_P$	C_L	0.021	0.670	1.260	1.490	1.680	1.875	1.675	Unstable	1.168	1.136	1.244
	C_D	.0118	.0146	.0290	.0415	.0587	.0775	.1700		.4930	.6000	.7370
	C_{DS}	.0083	.0085	.0085	.0086	.0087	.0087	.0085		.0088	.0088	.0089
	C_D+C_{DS}	.0201	.0231	.0375	.0501	.0674	.0862	.1785		.5018	.6088	.7459
	C_Q	.0041	.0043	.0043	.0043	.0044	.0044	.0043		.0044	.0044	.0045
Pressure $=6C_P$	C_L	0.1080	0.7950	1.430	1.709	1.955	2.200	2.340	Unstable	1.190	1.180	1.258
	C_D	−.0040	−.0010	.0154	.0310	.0489	.0683	.0948		.4930	.6050	.7370
	C_{DS}	.0396	.0400	.0402	.0406	.0410	.0417	.0917		.0407	.0408	.0414
	C_D+C_{DS}	.0356	.0390	.0556	.0716	.0899	.1100	.1365		.5337	.6458	.7784
	C_Q	.0066	.0067	.0067	.0068	.0068	.0069	.0069		.0068	.0068	.0069
Pressure $=12C_P$	C_L	0.1860	0.8800	1.548	1.858	2.160	2.410	2.540	Unstable	1.240	1.230	1.348
	C_D	−.0297	−.0246	−.0061	.0110	.0287	.0505	.0880		.5000	.6000	.7480
	C_{DS}	.1102	.1119	.1117	.1119	.1122	.1138	.1141		.1118	.1123	.1126
	C_D+C_{DS}	.0805	.0873	.1056	.1229	.1409	.1643	.2021		.6118	.7123	.8606
	C_Q	.0092	.0093	.0093	.0093	.0094	.0095	.0095		.0093	.0094	.0094

TABLE XIII.—N. A. C. A. 84–M PROFILE; SLOT 53.9 PER CENT OF CHORD FROM LEADING EDGE; SLOT OPEN 0.500 PER CENT CHORD

	α in degrees	−6	0	6	9	12	15	18	21	24	27	30
No flow through slot	C_L C_D	0.0260 .0213	0.6890 .0249	1.220 .0388	1.368 .0532	1.469 .0754	1.535 .1232	1.519 .1978	1.461 .2780	1.150 .5140	1.134 .6190	1.240 .7630
Suction $=6\ C_P$	C_L C_D C_{DS} C_D+C_{DS} C_Q	0.1010 .0308 .0386 .0694 .0064	0.7780 .0341 .0378 .0719 .0063	1.384 .0485 .0398 .0883 .0066	1.636 .0634 .0417 .1051 .0069	1.865 .0796 .0424 .1220 .0071	2.070 .0947 .0442 .1389 .0073	2.195 .1176 .0478 .1654 .0080	Unstable	1.204 .5090 .0560 .5650 .0093	1.170 .6190 .0558 .6748 .0093	1.282 .7730 .0554 .8284 .0093
Suction $=2\ C_P$	C_L C_D C_{DS} C_D+C_{DS} C_Q	0.0880 .0246 .0058 .0304 .0029	0.7620 .0276 .0056 .0332 .0028	1.328 .0408 .0055 .0463 .0028	1.561 .0567 .0056 .0623 .0028	1.730 .0732 .0054 .0786 .0027	1.880 .0947 .0067 .1014 .0033	1.613 .1561 .0093 .1654 .0047	1.509 .2990 .0095 .3085 .0048	1.173 .5090 .0089 .5179 .0045	1.170 .6190 .0086 .6276 .0043	1.257 .7710 .0083 .7793 .0041
Static pressure	C_L C_D C_Q	−0.0340 .0189 .0028	0.5920 .0214 .0034	1.113 .0351 .0031	1.258 .0531 .0030	1.421 .0737 .0029	1.582 .0918 .0028	1.592 .1686 .0031	1.509 .2590 .0034	1.141 .4920 .0040	1.134 .5930 .0041	1.240 .7360 .0043
Pressure $=1\ C_P$	C_L C_D C_{DS} C_D+C_{DS} C_Q	−0.0080 .0117 .0049 .0166 .0036	0.6330 .0139 .0053 .0192 .0053	1.216 .0274 .0052 .0326 .0052	1.437 .0412 .0052 .0464 .0052	1.637 .0593 .0053 .0646 .0053	1.807 .0793 .0053 .0846 .0053	1.671 .1628 .0053 .1681 .0053	1.566 .2590 .0053 .2643 .0053	1.156 .4860 .0055 .4915 .0056	1.155 .5950 .0056 .6006 .0056	1.230 .7310 .0058 .7368 .0058
Pressure $=2\ C_P$	C_L C_D C_{DS} C_D+C_{DS} C_Q	0.0460 .0042 .0127 .0169 .0064	0.7150 .0065 .0133 .0198 .0066	1.314 .0219 .0131 .0350 .0065	1.560 .0366 .0134 .0500 .0067	1.767 .0556 .0135 .0691 .0068	1.962 .0745 .0136 .0881 .0068	2.035 .0989 .0135 .1124 .0068	1.596 .2480 .0134 .2614 .0067	1.156 .4950 .0137 .5087 .0069	1.143 .5940 .0139 .6079 .0069	1.258 .7360 .0142 .7502 .0071
Pressure $=6\ C_P$	C_L C_D C_{DS} C_D+C_{DS} C_Q	0.1570 −.0250 .0613 .0363 .0102	0.8570 −.0207 .0624 .0417 .0104	1.498 −.0024 .0622 .0598 .0104	1.789 .0151 .0628 .0779 .0105	2.070 .0334 .0635 .0969 .0106	2.315 .0529 .0638 .1167 .0106	2.440 .0870 .0645 .1515 .0107	1.740 .2520 .0632 .3152 .0105	1.219 .4970 .0628 .5598 .0105	1.210 .5930 .0630 .6560 .0105	1.335 .7390 .0652 .8042 .0109
Pressure $=12\ C_P$	C_L C_D C_{DS} C_D+C_{DS} C_Q	0.2610 −.0705 .1659 .0954 .0138	0.9890 −.0638 .1670 .1032 .0139	1.676 −.0437 .1675 .1238 .0140	2.010 −.0259 .1689 .1430 .0141	2.325 −.0079 .1700 .1621 .0142	2.570 .0168 .1702 .1870 .0142	2.727 .0265 .1712 .1977 .0143	Unstable	1.298 .5000 .1682 .6682 .0140	1.320 .6120 .1687 .7807 .0141	1.465 .7730 .1700 .9430 .0142

TABLE XIV.—N. A. C. A. 84–M PROFILE; SLOT 53.9 PER CENT OF CHORD FROM LEADING EDGE; SLOT OPEN 0.667 PER CENT CHORD

	α in degrees	−6	0	6	9	12	15	18	21	24	27	30
No flow through slot	C_L	0.0285	0.6480	1.230	1.375	1.473	1.540	1.530	1.480	1.151	1.125	1.255
	C_D	.0216	.0247	.0392	.0543	.0778	.1242	.1986	.2820	.5140	.6220	.7560
Suction =6 C_P	C_L	0.0750	0.7630	1.390	1.665	1.900	2.140	2.285	1.645	1.250	1.180	1.310
	C_D	.0341	.0365	.0502	.0637	.0793	.0933	.1200	.3140	.5250	.6270	.7770
	C_{DS}	.0459	.0450	.0473	.0494	.0512	.0529	.0574	.0714	.0703	.0682	.0682
	C_D+C_{DS}	.0800	.0815	.0975	.1131	.1305	.1462	.1774	.3854	.5953	.6952	.8452
	C_Q	.0077	.0075	.0079	.0082	.0085	.0088	.0096	.0119	.0117	.0114	.0114
Suction =2 C_P	C_L	0.0590	0.7500	1.340	1.575	0.1760	1.945	1.670	1.565	1.225	1.160	1.270
	C_D	.0263	.0282	.0423	.0570	.0747	.0953	.1585	.2930	.5200	.6170	.7600
	C_{DS}	.0070	.0065	.0067	.0068	.0074	.0080	.0119	.0121	.0116	.0113	.0107
	C_D+C_{DS}	.0333	.0347	.0490	.0638	.0821	.1033	.1704	.3051	.5316	.6283	.7707
	C_Q	.0035	.0032	.0034	.0034	.0037	.0040	.0060	.0061	.0058	.0056	.0054
Static Pressure	C_L	−0.0810	0.5520	1.075	1.235	1.440	1.622	1.625	1.565	1.185	1.155	1.250
	C_D	.0185	.0201	.0337	.0500	.0708	.0895	.1565	.2620	.4910	.5960	.7300
	C_Q	.0040	.0040	.0044	.0042	.0043	.0043	.0044	.0049	.0056	.0057	.0060
Pressure =1 C_P	C_L	−0.0360	0.6200	1.225	1.460	1.670	1.870	1.760	1.610	1.190	1.165	1.265
	C_D	.0089	.0095	.0234	.0364	.0540	.0755	.1510	.2360	.4910	.5980	.7250
	C_{DS}	.0070	.0072	.0070	.0072	.0073	.0074	.0075	.0075	.0077	.0077	.0079
	C_D+C_{DS}	.0159	.0167	.0304	.0436	.0613	.0829	.1585	.2435	.4987	.6057	.7329
	C_Q	.0070	.0072	.0070	.0072	.0073	.0074	.0075	.0075	.0077	.0077	.0079
Pressure =2 C_P	C_L	0.0340	0.7190	1.345	1.602	1.850	2.065	2.205	1.660	1.210	1.185	1.265
	C_D	−.0033	0	.0155	.0286	.0475	.0657	.0892	.2360	.4930	.5960	.7300
	C_{DS}	.0173	.0181	.0178	.0182	.0185	.0186	.0188	.0184	.0186	.0189	.0192
	C_D+C_{DS}	.0140	.0181	.0333	.0468	.0660	.0843	.1080	.2544	.5116	.6149	.7492
	C_D	.0086	.0090	.0089	.0091	.0093	.0093	.0004	.0092	.0093	.0095	.0096
Pressure =6 C_P	C_L	0.1640	0.8850	1.555	1.882	2.200	2.460	2.500	Unstable	1.270	1.275	1.380
	C_D	−.0447	−.0395	−.0227	−.0070	.0090	.0310	.0955		.4940	.5900	.7300
	C_{DS}	.0812	.0826	.0830	.0837	.0844	.0850	.0858		.0840	.0844	.0843
	C_D+C_{DS}	.0365	.0431	.0603	.0767	.0934	.1160	.1813		.5780	.6744	.8143
	C_Q	.0135	.0138	.0138	.0140	.0141	.0142	.0143		.0140	.0141	.0140
Pressure =12 C_P	C_L	0.2890	1.050	1.755	2.130	2.455	2.720	2.895	Unstable	1.563	1.405	1.540
	C_D	−.1076	−.1023	−.0833	−.0658	−.0478	−.0218	−.0312		.4900	.5900	.7580
	C_{DS}	.2178	.2195	.2200	.2212	.2231	.2231	.2241		.2210	.2220	.2227
	C_D+C_{DS}	.1102	.1172	.1367	.1554	.1753	.2013	.1929		.7110	.8120	.9807
	C_Q	.0182	.0183	.0184	.0185	.0186	.0186	.0187		.0184	.0185	.0186

TABLE XV.—N. A. C. A. 84–M PROFILE; SLOT 72.6 PER CENT OF CHORD FROM LEADING EDGE; SLOT OPEN 0.167 PER CENT CHORD

	α in degrees	−6	0	6	9	12	15	18	21	24	27	30
No flow through slot	C_L	0.0620	0.7240	1.235	1.398	1.484	1.530	1.515	1.456	1.145	1.145	1.243
	C_D	.0208	.0247	.0379	.0543	.0861	.1268	.2035	.2745	.5160	.6180	.7720
Suction $=6\ C_P$	C_L	0.0125	0.7810	1.349	1.565	1.607	1.612	1.565	1.508	1.163	1.173	1.272
	C_D	.0231	.0286	.0433	.0585	.0921	.1304	.2040	.2830	.5080	.6200	.7710
	C_{DS}	.0197	.0187	.0189	.0195	.0203	.0205	.0203	.0202	.0199	.0195	.0191
	C_D+C_{DS}	.0428	.0473	.0622	.0780	.1124	.1509	.2243	.3032	.5279	.6395	.7901
	C_Q	.0033	.0031	.0032	.0033	.0034	.0034	.0034	.0034	.0033	.0033	.0032
Suction $=2\ C_P$	C_L	0.0101	0.7580	1.305	1.500	1.540	1.570	1.533	1.493	1.168	1.150	1.240
	C_D	.0197	.0263	.0399	.0559	.0880	.1280	.2005	.2740	.5100	.6210	.7680
	C_{DS}	.0031	.0031	.0029	.0030	.0031	.0030	.0029	.0029	.0026	.0026	.0023
	C_D+C_{DS}	.0228	.0294	.0428	.0589	.0911	.1310	.2034	.2769	.5126	.6236	.7703
	C_Q	.0016	.0016	.0014	.0015	.0015	.0015	.0014	.0014	.0013	.0013	.0012
Static Pressure	C_L	0.0042	0.7030	1.197	1.365	1.491	1.550	1.540	1.480	1.153	1.142	1.245
	C_D	.0204	.0244	.0381	.0542	.0799	.1217	.1968	.2730	.5100	.6210	.7630
	C_Q	.0005	.0005	.0005	.0042	.0004	.0006	.0078	.0008	.0010	.0010	.0012
Pressure $=1\ C_P$	C_L	0.0039	0.7010	1.215	1.415	1.535	1.578	1.561	1.498	1.147	1.147	1.260
	C_D	.0186	.0220	.0362	.0505	.0740	.1161	.1909	.2710	.5110	.6170	.7620
	C_{DS}	.0013	.0013	.0013	.0013	.0013	.0014	.0015	.0015	.0016	.0017	.0017
	C_D+C_{DS}	.0199	.0233	.0375	.0518	.0753	.1175	.1924	.2725	.5126	.6187	.7637
	C_Q	.0013	.0013	.0013	.0013	.0013	.0014	.0015	.0015	.0016	.0017	.0017
Pressure $=2\ C_P$	C_L	0.0044	0.7110	1.250	1.471	1.604	1.599	1.561	1.506	1.147	1.142	1.262
	C_D	.0167	.0208	.0353	.0498	.0716	.1149	.1897	.2720	.5080	.6150	.7610
	C_{DS}	.0037	.0037	.0037	.0037	.0037	.0038	.0039	.0042	.0043	.0043	.0044
	C_D+C_{DS}	.0204	.0245	.0390	.0535	.0753	.1187	.1936	.2762	.5123	.6193	.7654
	C_Q	.0018	.0018	.0019	.0019	.0018	.0019	.0020	.0021	.0022	.0022	.0022
Pressure $=6\ C_P$	C_L	0.0096	0.7710	1.360	1.620	1.814	1.692	1.593	1.524	1.163	1.152	1.260
	C_D	.0089	.0147	.0310	.0474	.0678	.1142	.1885	.2730	.5070	.6140	.7610
	C_{DS}	.0213	.0213	.0215	.0215	.0215	.0213	.0217	.0215	.0223	.0224	.0225
	C_D+C_{DS}	.0302	.0360	.0525	.0689	.0893	.1355	.2102	.2945	.5293	.6364	.7835
	C_Q	.0036	.0036	.0036	.0036	.0036	.0035	.0036	.0036	.0037	.0037	.0038
Pressure $=12\ C_P$	C_L	0.0148	0.8350	1.459	1.728	1.983	1.828	1.648	1.581	1.178	1.197	1.303
	C_D	−.0029	.0043	.0221	.0401	.0568	.1142	.2005	.2750	.5080	.6140	.7630
	C_{DS}	.0644	.0648	.0652	.0652	.0651	.0651	.0651	.0655	.0658	.0663	.0666
	C_D+C_{DS}	.0615	.0691	.0873	.1053	.1219	.1793	.2656	.3405	.5738	.6803	.8296
	C_Q	.0054	.0054	.0054	.0054	.0054	.0054	.0054	.0055	.0055	.0055	.0056

TABLE XVI.—N. A. C. A. 84–M PROFILE; SLOT 72.6 PER CENT OF CHORD FROM LEADING EDGE; SLOT OPEN 0.333 PER CENT CHORD

	α in degrees	−6	0	6	9	12	15	18	21	24	27	30
No flow through slot	C_L	0.0620	0.7210	1.228	1.390	1.464	1.532	1.517	1.446	1.136	1.123	1.251
	C_D	.0214	.0246	.0377	.5280	.8500	.1261	.2020	.2805	.520	.6140	.7580
Suction $=6\ C_P$	C_L	0.1370	0.8250	1.415	1.660	1.834	1.658	1.608	1.509	1.152	1.193	1.277
	C_D	.0287	.0324	.0481	.0638	.0833	.1429	.2200	.3020	.5200	.6340	.7910
	C_{DS}	.0322	.0322	.0333	.0345	.0356	.0376	.0378	.0384	.0382	.0376	.0372
	C_D+C_{DS}	.0609	.0646	.0814	.0983	.1189	.1805	.2578	.3404	.5582	.6716	.8282
	C_Q	.0054	.0054	.0056	.0057	.0059	.0063	.0063	.0064	.0064	.0063	.0062
Suction $=2\ C_P$	C_L	0.1290	0.7930	1.360	1.570	1.610	1.584	1.545	1.483	1.152	1.193	1.261
	C_D	.0223	.0282	.0433	.0580	.0939	.1332	.2090	.3020	.5200	.6340	.7640
	C_{DS}	.0049	.0046	.0047	.0054	.0057	.0059	.0057	.0057	.0054	.0053	.0047
	C_D+C_{DS}	.0272	.0328	.0480	.0634	.0996	.1391	.2147	.3077	.5254	.6393	.7687
	C_Q	.0024	.0023	.0024	.0027	.0029	.0030	.0029	.0029	.0027	.0027	.0024
Static pressure	C_L	0.0390	0.7000	1.194	1.378	1.512	1.563	1.535	1.489	1.152	1.168	1.250
	C_D	.0203	.0237	.0369	.0516	.0772	.1191	.1932	.2763	.5130	.6150	.7100
	C_Q	.0012	.0013	.0012	.0011	.0014	.0014	.0017	.0020	.0020	.0024	.0025
Pressure $=1\ C_P$	C_L	0.0440	0.7130	1.273	1.498	1.648	1.610	1.566	1.499	1.152	1.158	1.261
	C_D	.0158	.0191	.0336	.0479	.0672	.1126	.1841	.2733	.5130	.6180	.7560
	C_{DS}	.0028	.0029	.0029	.0029	.0028	.0030	.0031	.0030	.0035	.0036	.0040
	C_D+C_{DS}	.0186	.0220	.0365	.0508	.0700	.1156	.1872	.2763	.5165	.6216	.7600
	C_Q	.0028	.0029	.0029	.0029	.0029	.0030	.0031	.0030	.0035	.0036	.0040
Pressure $=2\ C_P$	C_L	0.0730	0.7650	1.333	1.570	1.764	1.645	1.582	1.520	1.158	1.172	1.261
	C_D	.0116	.0152	.0307	.0462	.0664	.1126	.1841	.2784	.5130	.6150	.7670
	C_{DS}	.0077	.0080	.0080	.0081	.0079	.0079	.0082	.0084	.0087	.0087	.0088
	C_D+C_{DS}	.0193	.0232	.0387	.0543	.0743	.1205	.1923	.2868	.5217	.6237	.7758
	C_Q	.0039	.0040	.0040	.0040	.0040	.0040	.0041	.0042	.0044	.0044	.0044
Pressure $=6\ C_P$	C_L	0.1580	0.8610	1.491	1.755	1.992	1.800	1.648	1.540	1.168	1.230	1.312
	C_D	−.0063	−.0016	.0174	.0347	.0529	.1126	.1965	.2920	.5160	.6230	.7680
	C_{DS}	.0394	.0394	.0396	.0398	.0398	.0397	.0399	.0399	.0409	.0411	.0415
	C_D+C_{DS}	.0331	.0378	.0570	.0745	.0927	.1523	.2364	.3319	.5569	.6641	.8095
	C_Q	.0066	.0066	.0066	.0066	.0066	.0066	.0067	.0067	.0068	.0069	.0069
Pressure $=12\ C_P$	C_L	0.2390	0.9570	1.632	1.947	2.245	2.110	1.731	1.655	1.235	1.312	1.405
	C_D	−.0330	−.0265	−.0072	.0111	.0280	.1003	.1996	.2992	.5200	.6340	.7980
	C_{DS}	.1108	.1108	.1114	.1114	.1119	.1120	.1120	.1123	.1126	.1123	.1132
	C_D+C_{DS}	.0778	.0843	.1042	.1225	.1399	.2123	.3116	.4115	.6326	.7463	.9112
	C_Q	.0092	.0092	.0093	.0093	.0093	.0093	.0093	.0094	.0094	.0094	.0095

TABLE XVII.—N. A. C. A. 84–M PROFILE; SLOT 72.6 PER CENT OF CHORD FROM LEADING EDGE; SLOT OPEN 0.500 PER CENT CHORD

	α in degrees	−6	0	6	9	12	15	18	21	24	27	30
No flow through slot	C_L	0.0413	0.6920	1.219	1.390	1.480	1.534	1.528	1.472	1.164	1.144	1.242
	C_D	.0209	.0246	.0378	.0515	.0809	.1242	.1965	.2702	.5110	.6110	.7620
Suction $=6\ C_P$	C_L	0.1190	0.8110	1.428	1.685	1.913	1.725	1.620	1.538	1.173	1.185	1.306
	C_D	.0310	.0345	.0494	.0657	.0829	.1489	.2260	.3110	.5270	.6410	.7820
	C_{DS}	.0429	.0448	.0468	.0487	.0511	.0564	.0579	.0581	.0563	.0564	.0512
	C_D+C_{DS}	.0739	.0793	.0962	.1144	.1340	.2053	.2839	.3691	.5833	.6974	.8332
	C_Q	.0072	.0075	.0078	.0081	.0085	.0094	.0096	.0097	.0094	.0094	.0092
Suction $=2\ C_P$	C_L	0.1060	0.7720	1.368	1.590	1.772	1.640	1.580	1.492	1.168	1.163	1.285
	C_D	.0244	.0289	.0437	.0593	.0775	.1345	.2180	.3000	.5190	.6280	.7770
	C_{DS}	.0068	.0070	.0068	.0078	.0088	.0102	.0102	.0094	.0086	.0085	.0079
	C_D+C_{DS}	.0312	.0359	.0505	.0671	.0863	.1447	.2282	.3094	.5276	.6365	.7849
	C_Q	.0034	.0035	.0034	.0039	.0044	.0051	.0051	.0047	.0043	.0043	.0040
Static pressure	C_L	0.	0.6470	1.152	1.362	1.530	1.590	1.565	1.492	1.142	1.158	1.258
	C_D	.0197	.0223	.0350	.0485	.0690	.1107	.1900	.2810	.5090	.6130	.7560
	C_Q	.0020	.0021	.0021	.0021	.0021	.0027	.0031	.0035	.0040	.0041	.0042
Pressure $=1\ C_P$	C_L	0.0210	0.6940	1.278	1.520	1.707	1.667	1.590	1.510	1.153	1.158	1.269
	C_D	.0124	.0151	.0289	.0439	.0517	.1050	.1862	.2840	.5090	.6150	.7610
	C_{DS}	.0044	.0046	.0048	.0048	.0048	.0049	.0051	.0054	.0054	.0055	.0057
	C_D+C_{DS}	.0168	.0197	.0337	.0487	.0565	.1099	.1913	.2894	.5144	.6205	.7667
	C_Q	.0044	.0046	.0048	.0048	.0048	.0049	.0051	.0054	.0054	.0055	.0057
Pressure $=2\ C_P$	C_L	0.0650	0.7520	1.360	1.620	1.830	1.740	1.610	1.530	1.178	1.189	1.306
	C_D	.0051	.0083	.0236	.0390	.0588	.1055	.1905	.2890	.5090	.6140	.7660
	C_{DS}	.0117	.0123	.0125	.0127	.0127	.0128	.0132	.0134	.0134	.0135	.0137
	C_D+C_{DS}	.0168	.0206	.0361	.0517	.0715	.1183	.2037	.3024	.5224	.6275	.7797
	C_Q	.0059	.0061	.0063	.0064	.0064	.0064	.0066	.0067	.0067	.0068	.0069
Pressure $=6\ C_P$	C_L	0.1760	0.8770	1.537	1.840	2.140	2.090	1.720	1.615	1.220	1.282	1.400
	C_D	−.0248	−.0192	−.0017	.0142	.0319	.0904	.1998	.3030	.5130	.6330	.7930
	C_{DS}	.0601	.0603	.0614	.0619	.0621	.0633	.0632	.0635	.0616	.0627	.0625
	C_D+C_{DS}	.0353	.0411	.0597	.0761	.0940	.1537	.2630	.3665	.5746	.6957	.8555
	C_Q	.0100	.0101	.0102	.0103	.0103	.0105	.0105	.0106	.0103	.0103	.0104
Pressure $=12\ C_P$	C_L	0.2850	1.008	1.718	2.070	2.380	2.540	1.870	1.730	1.320	1.402	1.539
	C_D	−.0692	−.0630	−.0435	−.0278	−.0080	.0127	.2104	.3000	.5130	.6440	.8290
	C_{DS}	.1659	.1665	.1681	.1692	.1693	.1701	.1702	.1702	.1645	.1653	.1666
	C_D+C_{DS}	.0967	.1035	.1246	.1414	.1613	.1828	.3806	.4702	.6775	.8093	.9956
	C_Q	.0138	.0139	.0140	.0141	.0141	.0142	.0142	.0142	.0137	.0138	.0138

TABLE XVIII.—N. A. C. A. 84–M PROFILE; SLOT 72.6 PER CENT OF CHORD FROM LEADING EDGE; SLOT OPEN 0.667 PER CENT CHORD

	α in degrees	−6	0	6	9	12	15	18	21	24	27	30
No flow through slot	C_L	0.0491	0.7020	1.215	1.382	1.465	1.530	1.508	1.474	1.130	1.150	1.250
	C_D	.0209	.0253	.0376	.0515	.0811	.1250	.1990	.2670	.4970	.6170	.7500
Suction =6 C_P	C_L	0.1350	0.8330	1.460	1.730	2.000	2.205	1.650	1.570	1.212	1.178	1.302
	C_D	.0327	.0361	.0513	.0670	.0800	.0903	.2225	.3000	.5270	.6310	.7900
	C_{DS}	.0475	.0506	.0530	.0558	.0581	.0640	.0691	.0687	.0665	.0662	.0662
	C_D+C_{DS}	.0802	.0867	.1043	.1228	.1381	.1543	.2916	.3687	.5935	.6972	.8562
	C_Q	.0079	.0084	.0088	.0093	.0097	.0107	.0115	.0115	.0111	.0110	.0110
Suction =2 C_P	C_L	0.1220	0.8000	1.395	1.640	1.830	1.680	1.595	1.540	1.186	1.152	1.288
	C_D	.0257	.0296	.0453	.0607	.0783	.1400	.2133	.2965	.5210	.6270	.7750
	C_{DS}	.0076	.0084	.0086	.0088	.0106	.0122	.0119	.0121	.0112	.0112	.0104
	C_D+C_{DS}	.0333	.0380	.0539	.0695	.0889	.1522	.2252	.3086	.5322	.6382	.7854
	C_Q	.0038	.0042	.0043	.0044	.0053	.0061	.0060	.0061	.0056	.0056	.0052
Static Pressure	C_L	−0.0050	0.6380	1.153	1.364	1.556	1.615	1.576	1.523	1.160	1.152	1.250
	C_D	.0195	.0213	.0342	.0482	.0663	.1060	.1783	.2625	.4990	.6040	.7500
	C_Q	.0025	.0029	.0029	.0024	.0026	.0036	.0041	.0044	.0052	.0051	.0056
Pressure =1 C_P	C_L	0.0290	0.7120	1.300	1.553	1.762	1.756	1.605	1.545	1.176	1.166	1.280
	C_D	.0095	.0117	.0270	.0410	.0585	.0960	.1774	.2765	.5010	.6040	.7600
	C_{DS}	.0058	.0060	.0061	.0062	.0063	.0064	.0067	.0069	.0072	.0073	.0075
	C_D+C_{DS}	.0153	.0177	.0331	.0472	.0648	.1024	.1841	.2834	.5082	.6113	.7675
	C_Q	.0058	.0060	.0061	.0062	.0063	.0064	.0067	.0069	.0072	.0073	.0075
Pressure =2 C_P	C_L	0.0800	0.7790	1.395	1.675	1.905	1.820	1.641	1.575	1.190	1.200	1.330
	C_D	−.0007	.0024	.0188	.0327	.0497	.1028	.1850	.2810	.5070	.6250	.7660
	C_{DS}	.0158	.0160	.0162	.0164	.0167	.0168	.0171	.0175	.0177	.0178	.0182
	C_D+C_{DS}	.0151	.0184	.0350	.0491	.0664	.1196	.2021	.2985	.5247	.6428	.7842
	C_Q	.0079	.0080	.0081	.0082	.0084	.0084	.0086	.0088	.0089	.0089	.0091
Pressure =6 C_P	C_L	0.2080	0.9350	1.622	1.940	2.180	2.215	1.795	1.685	1.258	1.307	1.458
	C_D	−.0411	−.0361	−.0189	−.0032	.0234	.0668	.1906	.2830	.5040	.6200	.7930
	C_{DS}	.0773	.0774	.0784	.0787	.0793	.0800	.0804	.0808	.0794	.0802	.0805
	C_D+C_{DS}	.0362	.0413	.0595	.0755	.1027	.1468	.2710	.3638	.5834	.7002	.8735
	C_Q	.0129	.0129	.0131	.0131	.0132	.0133	.0134	.0135	.0132	.0134	.0134
Pressure =12 C_P	C_L	0.3350	1.088	1.790	2.060	2.290	2.370	1.962	1.805	1.384	1.484	1.590
	C_D	−.1026	−.0958	−.0706	−.0332	.0200	.0454	.1920	.2805	.5030	.6400	.7910
	C_{DS}	.2081	.2099	.2099	.2105	.2135	.2148	.2148	.2148	.2108	.2115	.2115
	C_D+C_{DS}	.1055	.1141	.1393	.1773	.2335	.2602	.4068	.4953	.7138	.8515	1.003
	C_Q	.0173	.0175	.0175	.0175	.0178	.0179	.0179	.0179	.0176	.0176	.0176

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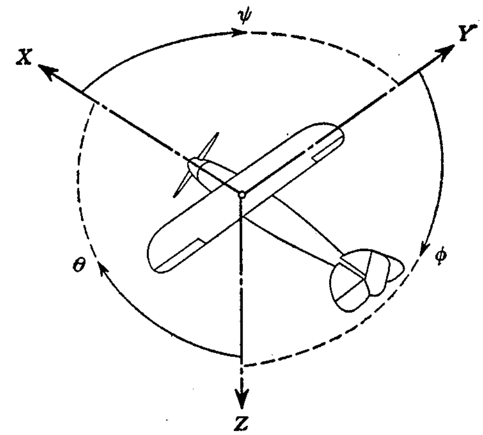

Positive directions of axes and angles (forces and moments) are shown by arrows

Axis		Force (parallel to axis) symbol	Moment about axis			Angle		Velocities	
Designation	Symbol		Designation	Symbol	Positive direction	Designation	Symbol	Linear (component along axis)	Angular
Longitudinal	X	X	rolling	L	$Y \longrightarrow Z$	roll	ϕ	u	p
Lateral	Y	Y	pitching	M	$Z \longrightarrow X$	pitch	θ	v	q
Normal	Z	Z	yawing	N	$X \longrightarrow Y$	yaw	ψ	w	r

Absolute coefficients of moment

$$C_l=\frac{L}{qbS} \qquad C_m=\frac{M}{qcS} \qquad C_n=\frac{N}{qbS}$$

Angle of set of control surface (relative to neutral position), δ. (Indicate surface by proper subscript.)

4. PROPELLER SYMBOLS

D, Diameter.
p, Geometric pitch.
p/D, Pitch ratio.
V', Inflow velocity.
V_s, Slipstream velocity.
T, Thrust, absolute coefficient $C_T=\frac{T}{\rho n^2 D^4}$
Q, Torque, absolute coefficient $C_Q=\frac{Q}{\rho n^2 D^5}$
P, Power, absolute coefficient $C_P=\frac{P}{\rho n^3 D^5}$.
C_s, Speed power coefficient $=\sqrt[5]{\frac{\rho V^5}{P n^2}}$.
η, Efficiency.
n, Revolutions per second, r. p. s.
Φ, Effective helix angle $=\tan^{-1}\left(\frac{V}{2\pi r n}\right)$

5. NUMERICAL RELATIONS

1 hp = 76.04 kg/m/s = 550 lb./ft./sec.
1 kg/m/s = 0.01315 hp
1 mi./hr. = 0.44704 m/s
1 m/s = 2.23693 mi./hr.
1 lb. = 0.4535924277 kg
1 kg = 2.2046224 lb.
1 mi. = 1609.35 m = 5280 ft.
1 m = 3.2808333 ft.